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THE GEOLOGY

of the

WESTERN BUCKSKIN MOUNTAINS

Yuma County, Arizona

By

RALPH C. BLANCHARD

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Submitted in Partial Fulfillment of the Requirements for the degree of Doctor of Philosophy in the Faculty of Pure Science of Columbia University

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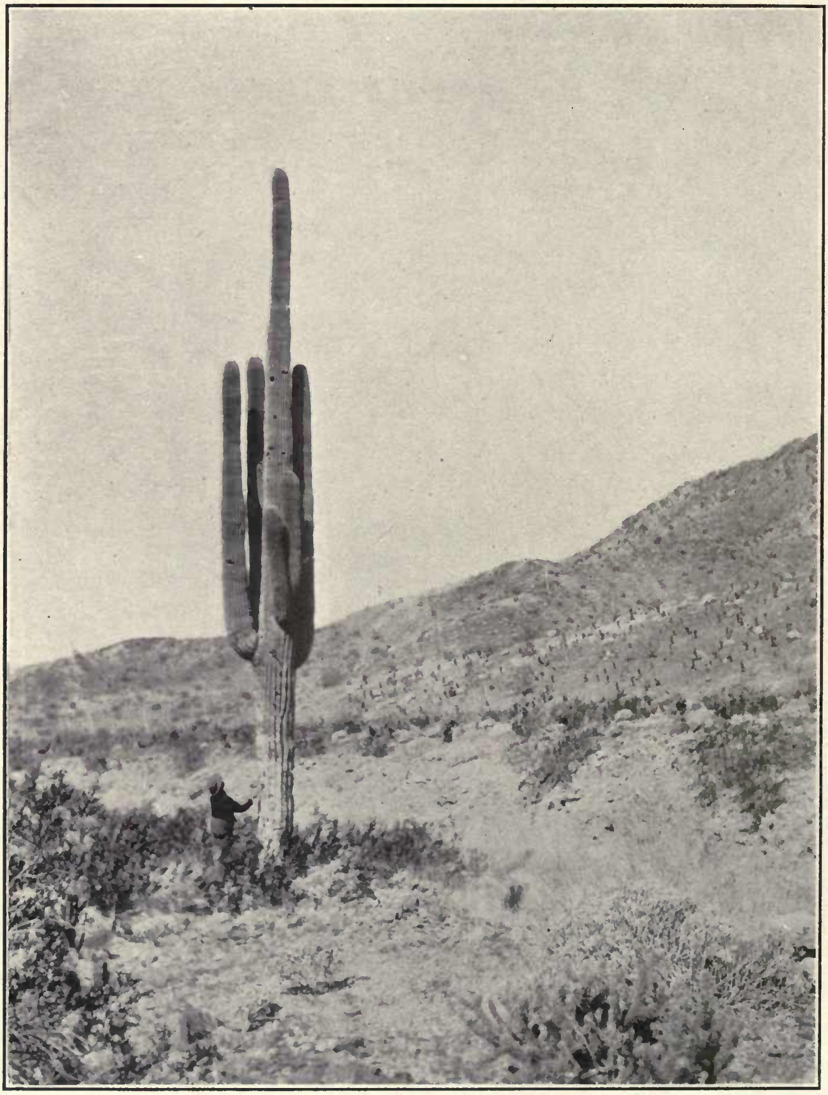

SAHUARO (CEREUS GIGANTUS)

THE GEOLOGY

of the

WESTERN BUCKSKIN MOUNTAINS

Yuma County, Arizona

VITA

Ralph Carpenter Blanchard—Born December 4, 1882 at Newport, Indiana, attended The Rose Polytechnic Institute from 1901 to 1905, receiving the degree of B. S. Civil Engineering courses were taken at the Harvard Engineering Camp in the Summer of 1904. Registered as Graduate Student in the Faculty of Pure Science Columbia University in the years 1905-06, 1908-09, 1912-13. Studied at the University of Munich, Germany, 1906-07. Since 1910 Mgr. Director of the Old York Trust Co. Ltd., London E. C.

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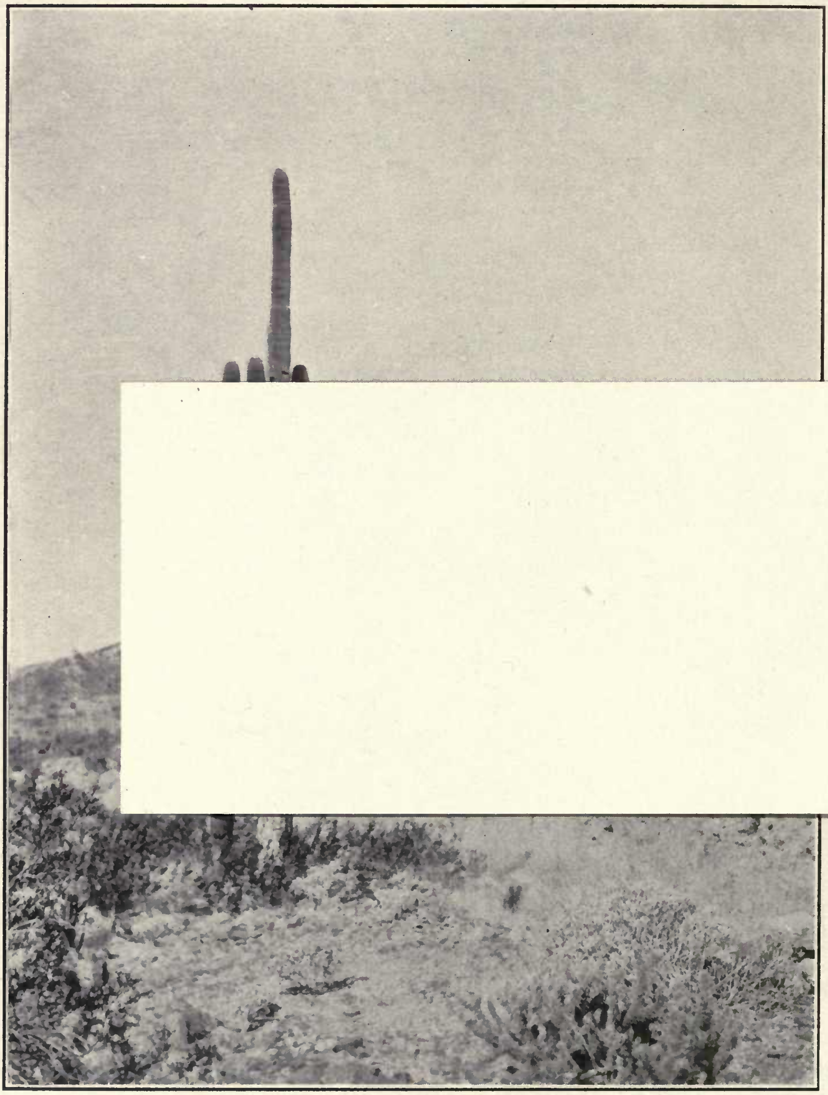

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INTRODUCTION.

Western Arizona is a part of that semi-arid region, the Lower Colorado Basin, one of the large physiographic provinces of the United States. To-day many of its portions remain blank upon the geologic map, and other parts are known only from reconnaisance surveys. The basement complex of granites, gneisses, porphyries, pegmatites and metamorphosed sediments is as yet unsolved as to origin or relationship to other Precambric and Algonkian rocks in Arizona and the conditions in Paleozoic time have still to receive a more detailed solution. The Mesozoic is largely a matter of conjecture and it is not until the Tertiary and Quaternary strata are reached that the region affords the necessary data for a satisfactory explanation of the conditions which existed. The economic resources have been the subject of some study and there is perhaps little to be added to the general knowledge in this particular. Besides gold, silver, copper, lead and mercury there is also the western type of hematite ores, whose genesis has been the subject of several recent investigations in different parts of the western United States.

This paper was prepared with the idea that a detailed study of any part of this region might perhaps add something to the knowledge of it. The rocks of the western part of the Buckskin Mountains, their relations to certain hematite deposits; and physiographic observations form the subject of the investigation.

Previous Literature:

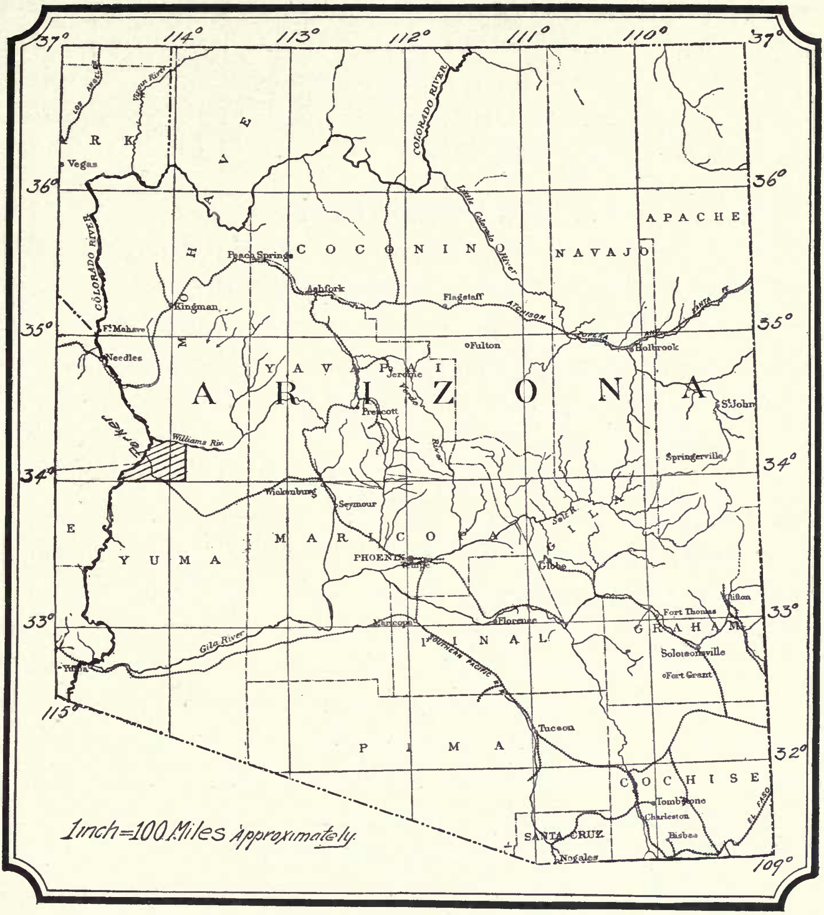
The Whipple expedition in 1853 made the first official report upon the region, but was not concerned with its geology. Jules Marcou, Thomas Antisell and William P. Blake were the first geologists to give an account of the Lower Colorado Basin. They were attached to the Pacific Railroad expedition in 1854-56. Benjamin Silliman and W. P. Blake in these early days contributed papers to the American Journal of Science, recording some of their observations. The report of Dr. J. S. Newberry, geologist to the Colorado Exploring Expedition, under command of Lieut. J. C. Ives in 1857-58, treats for the first time of the general geology of the Colorado River from its mouth to the head of navigation and it is in this report that one finds the first description of the geology in the vicinity of the mouth of the Williams River. This work of Newberry's, Major Powell's account of the Colorado, the reports of Gilbert, Marvin and Howell (Wheeler, 1871-73), and Dutton, are classics of the Lower Colorado Basin as they are of the great Basin and Colorado Plateau provinces in general. After the above contributions, except for occasional papers in the mining press, no reports appeared until 1903-04, when W. T. Lee, of the U. S. Geological Survey, made a reconnaisance of that part of the Basin, extending from the Colorado River east to the Grand Wash Cliffs and south to latitude 33° 30′; treating in a lucid and comprehensive manner of a region which to the geologist was practically virgin territory. F. C. Schrader (1906-07) shortly afterwards reported on the mineral deposits of Mohave County, Arizona, and supplied information long desired by the mining companies. A bulletin equally desirable and important was written by Howland Bancroft in 1909. His report covered territory from just north of the Williams River, south to latitude 33° 30′. In the same year the topographic map of the Parker Quadrangle was issued by the Government and included the northwestern part of Yuma County. Since then, in 1912, Mr. Waldemar Lindgren, in Bulletin No. 507, of the U. S. Geological Survey, in enumerating the western mining districts, has summed the knowledge of economic geology of Arizona.

The literature on western iron ores has enlarged within the last few years. Leith and Harder have probably contributed most extensively to the subject, especially in their Bulletin on the Iron Springs District, Utah, No. 338, of the U. S. Geological Survey.

Acknowledgments:

This work was done under the advisement of Professor James F. Kemp, to whom acknowledgment is made for advice, suggestions and criticisms. The writer wishes also to express his thanks for the assistance received from Professor Amadeus W. Grabau, and he is under especial obligation to Dr. Charles P. Berkey, without whose assistance the paper would probably not have been written. Dr. W. H. Dall, of the U. S. Geological Survey, kindly determined two fossil species for which the writer expresses his acknowledgments and thanks.

Map 1



OUTLINE MAP OF ARIZONA

LOCATION.

The Buckskin Mountains and their foothills lie in the northwestern part of Yuma County, Arizona.

The Williams River, a natural boundary line between Yuma County on the south and Mohave County to the north, is formed by the junction of the Big Sandy River and Date Creek and flows in a general westerly direction, joining the Colorado River at Latitude 34° 18′ 16″.9,[1] Longitude 114° 06′ 45″.0, fifteen miles northeast of Parker in a direct line, and about fifty miles south of Yucca, on the main line of the Santa Fe Railroad. This part of Yuma County is readily accessible from Parker, Arizona, on the Arizona-California Division of the Santa Fe Railroad. Parker is some ten hours from Los Angeles, seven from Prescott and six hours from Phœnix. Train connections are good and the service rapid.

From the railroad one must go either by wagon or by motor. Unless one is making for some definite place, readily reached, travelling by horse back is futile, owing to the scarcity of water and the difficulty of obtaining supplies en route. The roads cross detrital filled valleys or gravel filled washes, and three miles per hour is not often exceeded. The water holes on the map are as a rule dry and it is foolhardy to go unprovided with water for man and beast.

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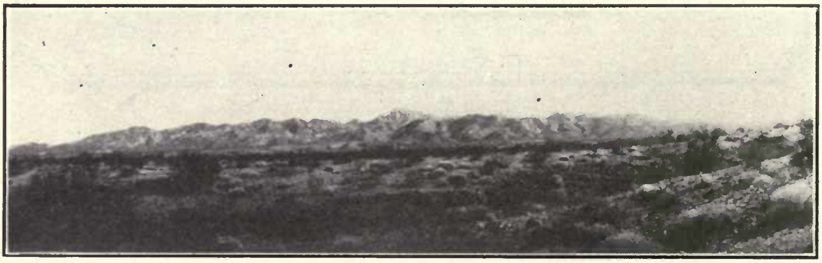
[1] Appendix B. Report upon the Colorado River of the West. Lieut. J. C. Ives, 1861.

TOPOGRAPHY.

With the exception of the mesas, the topography is that of the desert. The mountains rise in bare sloping ridges from the desert floor and the valleys are broad and filled with gravel, which extends well up the gentle mountain slopes. Where the valleys have sides other than those formed by these sloping ridges, they are apt to be steeply carved in thick beds of conglomerates capped by heavy flows of basalt. These steep sedimentary bluffs frequently show "bad land" topography, combined with that developed by wind erosion. The gradients of the mountain slopes change shortly after they leave the desert floor and they mount to a culminating point by a series of steep ridges. Each ridge is a razor-like divide, the water draining into steep narrow gulches, which finally widen as they reach the valleys or desert floor. The sides of the ridges owe their steepness to the shelving off of the rock along shear planes. The gulches end in a precipitous wall and consequently the easiest mode of ascent is by the ridges, keeping to the more favorable side.



BUCKSKIN MOUNTAINS

The highest point of the Buckskin Mountains is Planet Peak (3032′).[1] To the north of this peak the mountains break sharply and descend by steep sides into a broad wash, with a general elevation of from 1000 to 1200′. This wash is more or less parallel with the Williams River and is separated from it by foothills, which, three miles to the north, from the steep southern wall of the river itself.

To the south, long radiating ridges slope down to the desert, which from this height has all the aspects of the sea, the sand dunes brought out in relief by their shadows, appearing as an endless billowy surface.

[1] See page 80.

Here and there is a dark patch on the horizon, and the distant mountains sometimes resemble a full rigged ship, hull down. To the east can be seen the Harguahala and Harcuvar Ranges and in the immediate foreground, Squaw Peak, the next highest point of the Buckskins. The Whipple Mountains and the salient Monument Peak (2776′) form the western horizon, separated from the Buckskin range by the Colorado River (400′) and a high mesa, which rises—not far from its banks and extends east towards Planet Peak, until it breaks to form the steep side of an intervening valley (1150′). This mesa is similar to the many mesas of Arizona, with their broad areas, developing a drainage on their surface, individual to themselves. On the north the mesa is cut in an east and west direction by the Williams River, whose southern bank is a precipitous wall. It is cut in a north and south line by Mineral Wash, having a western wall only 500 or 600 feet lower than that of the Williams. The mesa slopes decidedly to the south and is not so high above Osborne Wash, which again traverses it in an east and west direction. To the south of Osborne Wash the mesa ends in two high peaks, which rise sharply from the Cactus Plain on the south. One of them is known as Black Peak. It remains only to mention the north wall of the Williams River, which is equally high with the southern, but is composed of poorly consolidated detrital beds with intercalated flows of basalt. This wall has yielded to the erosive action of the river, which has broadened its valley by sapping the gravel beds. The dissected lava beds, tilting to the southwest, add to its distinctiveness from the country to the south.

DRAINAGE.

The drainage is conformable to the basement rock. About six miles south of the Williams River in Mineral Wash there is a low divide. The waters flowing north cut through the superimposed sandstones and gravels, but only a short way into the basement floor. The waters flowing south finally enter Osborne Wash and the Colorado. It is to be noted that Osborne Wash has an elevation of 800 feet, while that of the Cactus Plain to the immediate south is somewhat higher. Nevertheless, there is practically no drainage into the Wash, the precipitation probably being absorbed by the desert sands and finding an outlet along the sloping basement floor to the south into Bouse's Wash.

On the eastern side of the Buckskin Mountains at Midway the northwest-southeast divide turns the waters off the foothills, just south of the Williams, into that river, while the waters from the other side of the range take the longer route into Bouse's Wash and thereby into the Colorado.

On the mesa, almost from the William's Wall, the waters flow south, separating into various channels which lead into the lower part of Mineral Wash, or into the Colorado by a direct southwesterly route. This feature is worthy of some note as it is indicative of a drainage in recent times dissimilar to the one of to-day, which apparently is controlled at present by divides which existed previous to the deposition of the Temple Bar Conglomerate.

Some miles west of the confluence of the Big Sandy and Date Creek the Williams River cuts through the Williams Canyon, which separates the Aubrey Hills from the Buckskin Mountains. It flows in a general northwesterly direction to the Colorado and has running water the year round, beyond Planet. At several points along its course it sinks out of sight during parts of the year. It is subject to high water for short periods, when precipitation has been heavy, and the washes and gulches at such times are also filled with torrents.

PRECIPITATION AND CLIMATE.

Rains usually occur in March, April, June and July, the last two being the months of heaviest precipitation. These rains are mostly in the afternoon and evenings. The sky clears almost at once. During the autumn it may drizzle for a day or two, but such form of rain is the exception, the general rule being a cloud-burst which gives torrents with enormous erosive power. In this part of Yuma County there are no records of the annual precipitation.

Those of Phoenix and Fort Mohave are available and a mean of the conditions existing in these two places, will probably approach the conditions prevailing in the Buckskin Mountains.

ANNUAL PRECIPITATION.

	Max.	Min.	Mean.	Annual Evaporation Estimated.	Ratio.
Phoenix (18 years)........	12.83	3.77	7.06	90	12.7
Fort Mohave (26 years)....	21.38	2.30	4.97	95	19.1

At Parker, the annual precipitation recorded during eight years is 4.27"[1]. More rain falls around the Williams River and in the mountains. During January a light fall of snow may occur, covering the higher peaks for a short time. In the summer months the heat is excessive, registering as high as 127° F. with a mean annual temperature at Parker of 70.9° for twelve years. On January 7, 1913, on the Williams River the temperature dropped to 13°, the lowest temperature experienced by Senor Ramone, who has lived in the valley for over twenty years. On the same date ice was seen in this part of the

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[1] Bancroft, H. Bull. U.S.G.S. 451, p. 13.

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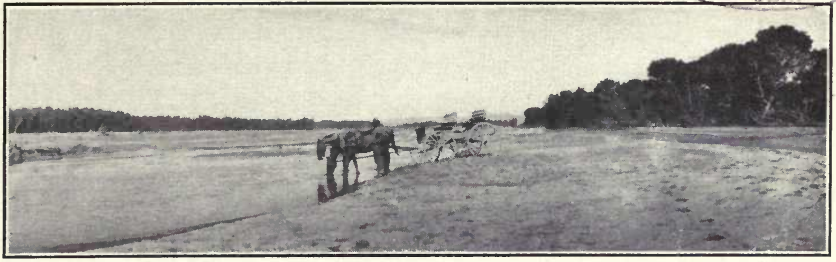
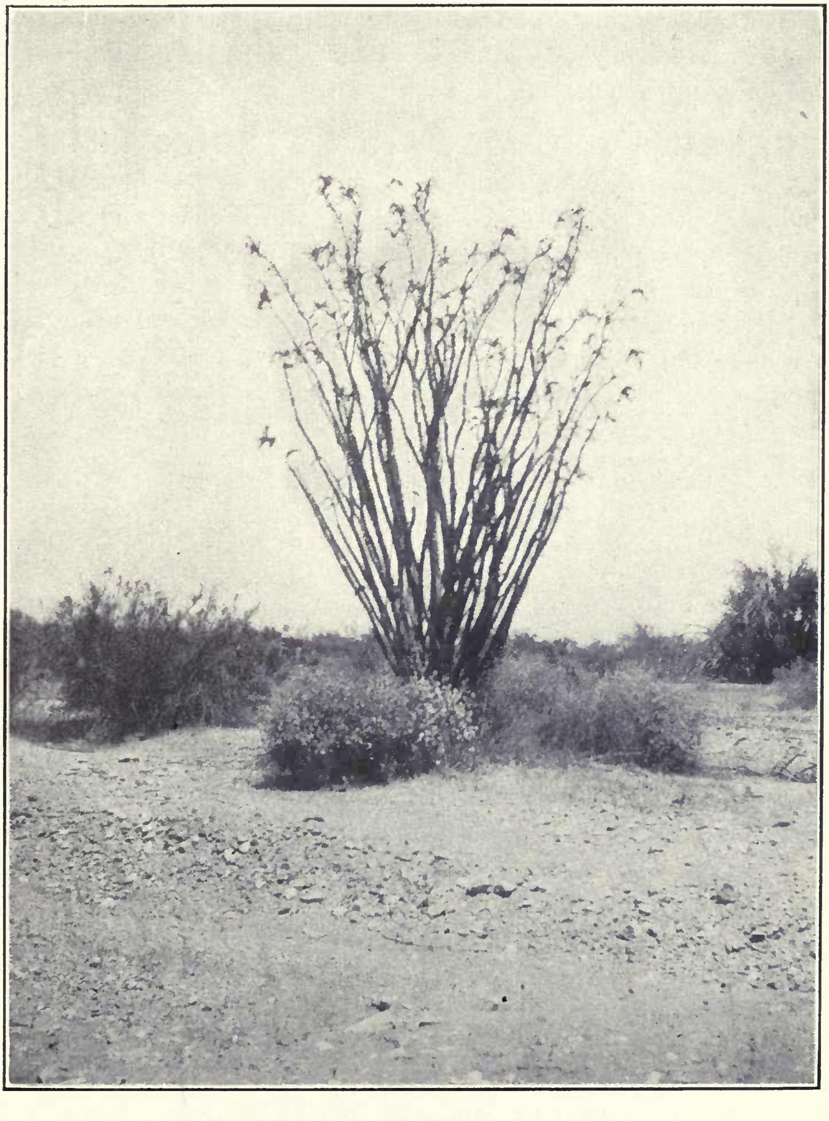


WILLIAMS RIVER



OCOTILLO, WITH WHITE BRITTLE BUSH AT ITS BASE

Colorado River, an event which was said not to have happened in thirty years. Blinding wind storms occur both in the winter and autumn months. The winds are usually from the southwest or northwest.

VEGETATION.

The character of the vegetation is dependent upon the elevation. On the foothills grow many varieties of cacti, of which the Bigelow cholla (Opuntia bigelovii), sahuaro (Cereus gigantus) and ocotillo (Cerecidium terreganum) with its vermilion flowers, are the most common. The sentinel-like mescal is to be found growing above 2300′ or thereabouts. Greasewood and the white brittle-bush with its canary colored flowers are conspicuous. In the washes grow mesquite, Palo Verde, cat claw, and iron wood, while along the Williams and Colorado Rivers grow also the cottonwood and desert willow. The fig and pomegranate grow under cultivation. For extensive use there is practically no timber.

GENERAL GEOLOGY AND PETROGRAPHY.

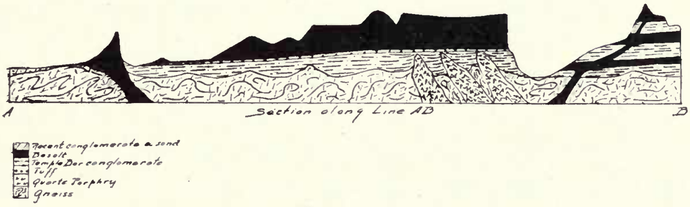
The rocks of the Buckskin Mountains are outlined as to their distribution on Map 2, and are designated Precambric and Quaternary in age. It is not proven, however, that some of the rocks referred to the latter age, are of that age and there is some evidence to be considered which might relegate them to the Tertiary. For uniformity and conciseness some of these rocks are given the correlation assigned them tentatively by W. T. Lee, of the U. S. Geological Survey. Arranged in a geologic column the rocks are as follows:

Quaternary	Recent gravels—Sand dunes.
	Calcareous—Siliceous—Hot Spring Deposits.
" (?)	Basalt.
	Tuffs.
	Rhyolite porphyry.
	Temple Bar Conglomerate (?).
Precambric	Erosion interval.
	Metamorphosed sediments, quartz—mica schists, limestones.
	Erosion interval.
	Rhyolite porphyry.
	Gneiss complex (intrusive).
	Pure dolomites and limestones—Algonkian ?

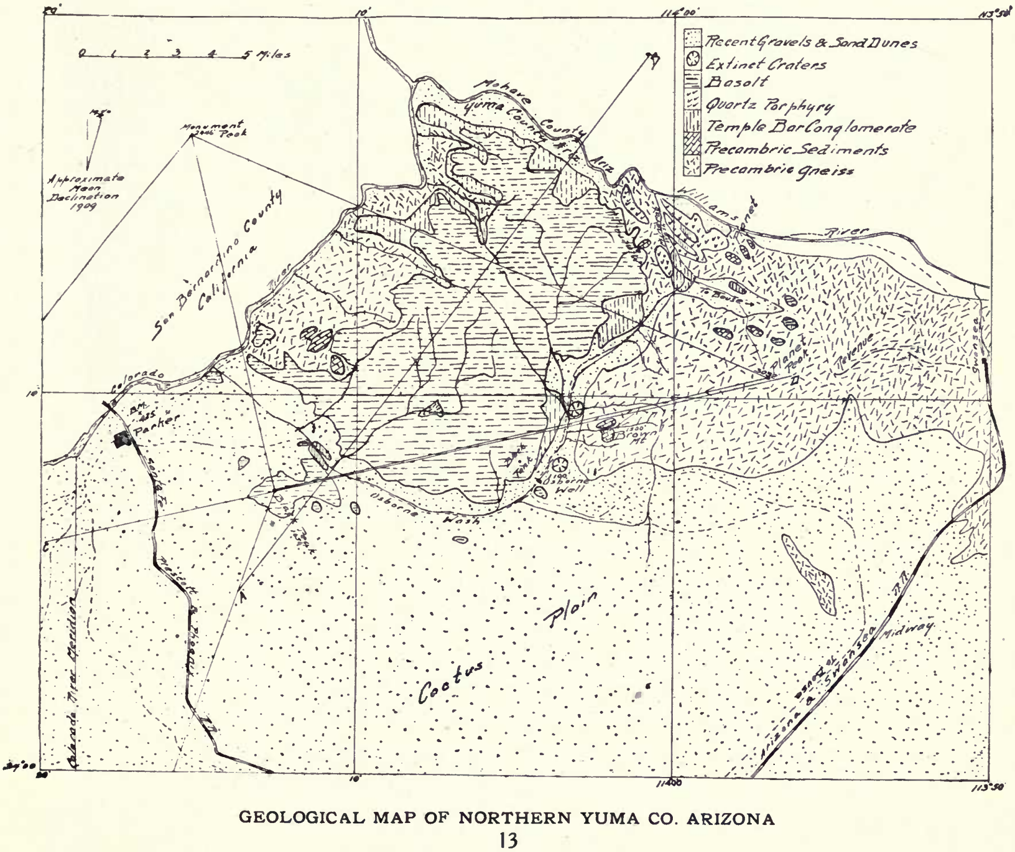
The basement rock has been assigned to the Precambric and is a part of the basement rock of western Arizona. Throughout the entire area it is reported as consisting of granites, gneisses, schists, and metamorphosed limestone and other sediments. The Algonkian, as developed in the Grand Canyon and known as the Grand Canyon series, has not been reported in western Arizona. The Paleozoic is absent, except for a few possible remnants near Kingman[1], but the rocks of this period, well developed in the Grand Wash Cliffs, are generally considered to have extended across Arizona to the west. The Mesozoic is also absent, but near this district, Bancroft[2] tentatively assigns an intrusive granite in the Harcuvar range to this period. Flows of lava, intrusives of

[1] Schrader, F. C. Bull. U.S G.S. 397, p. 30.
[2] Bancroft, H. Bull. U.S.G.S. 451, p. 29.

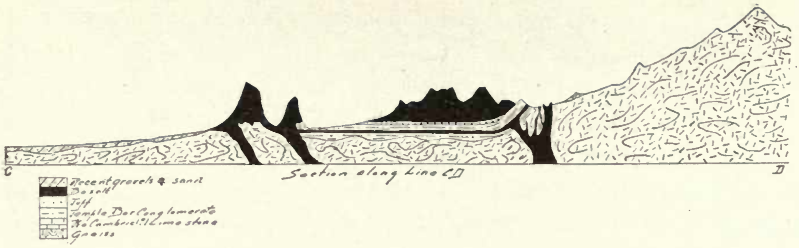
andesites and various other rocks of igneous origin and Tertiary age are found in the entire area, but none in this immediate district can be definitely so designated. The Quaternary, as considered by W. T. Lee, is represented by great thicknesses of detrital material, the Temple Bar Conglomerate and lava flows. Recent volcanic cones, with their craters filled with convoluted masses of basalt are striking features. More recent than the basalts are the numerous small fans and deposits of detrital material, the former cemented with a siliceous and calcareous matrix. The sand dunes of the desert are recent and represent an accumulation of eroded material, sifted and worn by a constant and effective wind action. Unconsolidated gravels of recent origin cover the flanks of the mountains and overlie basal gneiss and Temple Bar conglomerate. The age of the ore deposits and some associated rocks will be mentioned later.



Map 2



GEOLOGICAL MAP OF NORTHERN YUMA CO. ARIZONA



Precambric Basement Complex:

As previously stated, the basement complex of Western Arizona has been assigned to the Precambric. Van Hise[1] observes that the Precambric granites and basement complex of Arizona are probably not all of that age and that further study will differentiate certain portions of it to other time divisions. Bancroft[2] has recently designated part of the Harcuvar range as of later age and this case is probably typical of other discriminations which will from time to time be made.

The facts so far known show this basement foundation to be a complex of normal granites, gneisses, schists, with pronounced schistosity (and also with imperceptible gradation into the granites) metamorphosed limestones, pure and otherwise, argillites, quartzites and schists developed by the metamorphism of feldspathic shales and other sediments. Besides these are numerous intrusives, including pegmatites, aplites, quartz porphyries and diabases, all of which have later experienced the same dynamo-metamorphism as the rock into which they were intruded.

Schrader[3] describes the basement in Mohave County to the north as follows: "As a whole the Precambrian rocks consist of gneissoid granites, which are of varying degrees of schistosity, but which always preserve indications of their igneous origin. They are coarse grained and usually gray or reddish in color and consist of quartz, microcline, orthoclase, microperthite, oligoclase and small amounts of biotite. The original structure is eugranitic. With increasing schistosity the crushing of the constituents becomes more apparent and muscovite develops from feldspars and biotite, while chlorite forms from the biotite."

Bancroft[4] thus describes the granites and igneous schists of the area south of Mohave County: "Thin sections of the granitic gneiss examined . . . . show holocrystalline structure and a composition of microcline and orthoclase feldspar, with perhaps a little albite, associated with considerable quartz and a noticeable amount of biotite. Some augite is present in the rocks and a very small amount of calcite. Each mineral is remarkably fresh, even the feldspars, showing hardly any signs of sericitization. The schists have in general the same composition as the gneisses, the difference between the rocks being merely textural."

Albert Johannsen[5] describes the basement rock from the south end of

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[1] Bull. U.S.G.S. 397, p. 28.
[2] Bull. U.S.G.S. 451, p. 29.
[3] Bull. U.S.G.S. 397, p. 28.
[4] Bull. U.S.G.S. 451, p. 24.
[5] Bull. U.S.G.S. 352, p. 81.

Hulapai Mountains and from the mouth of the Williams as being under the microscope "hypautomorphic granular." "In both, the minerals are feldspar less quartz and still less biotite. Zircon and apatite are accessory. The feldspar is chiefly orthoclase, which is now and then intergrown with plagioclase in the form of microperthite; a little microcline and a little oligoclase or andesine occur. The biotite occurs in shreds and patches and is in many specimens considerably altered to iron oxide, so that it is black and opaque. Zircon occurs as short, stout, rounded grains and apatite both in small and thin and in large and stout prisms, the latter being sometimes irregular in form. The accessories occur within both the quartz and the feldspars."

From the Williams Canyon he describes the black and white banded gneiss as follows: "Under the microscope the texture is markedly schistose. The constituents are irregular or rounded grains, very variable in size, of hornblende, orthoclase, some plagioclase and a little quartz. There is much chlorite and a little epidote and titanite."

Van Hise[1] describes the Archean as exposed in the Grand Canyon as follows: "Black hornblende gneiss and light colored granite are abundant. In many cases these are interlaminated. In some places the gneisses are distinctly banded; in others they are distinctly foliated or schistose. The gneisses are cut by various granites in the most complex manner and great exposures show the dikes ramifying and coming together in the most fantastic manner. This indicates that before the granites were intruded the old gneisses had been completely deformed. Dark colored gneisses seem to be the oldest rocks in the series." He considers his description of the Lake Superior Archean to apply "exactly" to these.

The above descriptions are of rocks selected over a large part of a great area and it is noteworthy that the normal type or unaltered original rock is a small amount of the entire rock mass and there is no microscopic description of it.

The rocks of the Buckskin Mountains fail to give a normal type and a composite description would show a similarity to the above rocks, but would differ in many particulars.

Megascopically, the basement rock in this range is a prevailing light gray in color, fresh, and shows no phenocrysts. The texture in the field is felsitic. Marked schistosity is frequently displayed and the entire rock mass is traversed by shear planes, with a prevailing northwest-southeast direction. Joint planes, developed at right angles to the shear planes, give the rock a blocky habit. When the schistosity is pronouncedly developed, the rock shows a decided alignment of dark and light colored minerals. This phase of the rock is less frequent than the prevailing felsitic texture. In less amount are dark, greenish felsitic rocks, conformable in all other respects to the rock mass. It should also be noted that frequently, along the washes, due to the development of chlorite, the basement rock has a greenish cast.

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[1] Van Hise, Bull. U.S.G.S. 360, p. 775.

A sample taken at the southwest base of the range gave results approaching nearest to the normal type. (17 Gneiss.) The texture is granitoid. The rock is composed of large crystals with no groundmass. Many of the crystals are hypidiomorphic, but as a rule, their crystal boundaries have been altered by dynamic action. The force has been sufficient to fracture, distort and crush the mineral components and has developed distinct parallel zones, in which the large crystals have been crushed into small fragments. The principal minerals are feldspars. The section has a low relief and the feldspars show uniform low order grays. The rock is, as a whole, fresh. Microcline predominates and some of the crystals are quite large and retain some of their crystal boundaries complete. Polysynthetic twinning after both albite and pericline laws (gridiron structure) is completely developed. The mineral also has its characteristic small extinction angle, which eliminates any doubt but that the crossed twinning is that of microcline and not due to a strained condition existing throughout the section. Most of the crystals are badly fractured and shattered. Inclusions of apatite occur. Plagioclase is next in amount. The banding as a rule is narrow. One or two crystals show a somewhat wider twinning. Crystal boundaries are not so numerous as in the case of microcline. The crushing forces have distorted most of the crystals, destroying the crystal boundaries and in instances, tearing the crystal in parts without, however, disturbing the alignment of the twinning of the separate sections. Several cases show a slight bending. In zones of greatest crushing, this feldspar shows alteration, almost sufficient to obscure the banding. Wavy extinction is noted at times, also zonal growth. Several sections at right angles to the brachy-pinacoid allow of a determination of the plagioclase by the Michel Levy method. Extinction. angles from 13° to 16° were obtained, which would determine the plagioclase to be albite. Orthoclase is present in amount almost equal to that of plagioclase. It is always fresh and retains some of its crystal boundaries, in most cases, in that part of the section least disturbed. Parallel cleavage lines can be frequently seen. Twinning is absent.

Apatite crystals occur scattered throughout the rock, ranging in size from minute to fairly large. They are also seen as inclusions in the feldspars. Chlorite occurs as a secondary mineral, filling the fractures in the feldspars, the spaces between the crystals and along the twinning planes. As a rule, it is in irregular aggregates, with veinlets running out in various directions. It is light green in color and is often altered to a brown color, which remains dark under crossed nicols. The anomalous interference color of Berlin blue is markedly developed. Alterations of the plagioclase crystals is common near large aggregates of the chlorite.

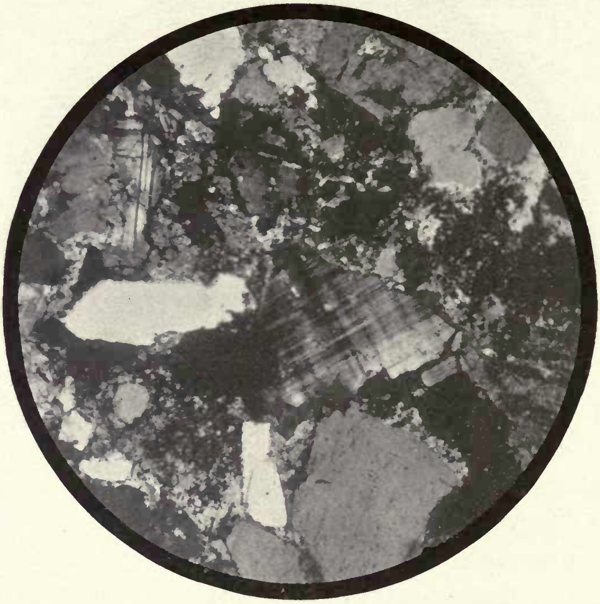
GNEISS

Quartz occurs to a small extent as a primary mineral, also in the crushed zones as a secondary mineral. The grains are quite small and granular, and are arranged in mosaic patterns. At times the quartz aggregate penetrates into the feldspars but has effected little corrosion.

A marked characteristic of the crush zones is an absence of a pronounced alignment of the minerals and the well preserved character of the crushed fragments of feldspars filling these zones. Secondary quartz and chlorite appear to be the only minerals introduced and developed incident to the crushing. Portions of the section show such a slight alteration of the original minerals and so little disturbance that it is assumed these portions represent the original condition of the rock. It is evident that the rock has been subjected to heavy dynamic forces, accompanied or followed by the introduction of quartz and development of chlorite. There is an absence of alignment of the original minerals which is developed in other parts of the area. The absence of hematite is also to be noted.

On Planet Peak the rock strikes about N 25° W (true north).

Orthoclase was found to be the predominating phenocryst, some of the crystals being quite large, showing some alteration to sericite. Parallel cleavage is well developed in the large phenocrysts. The crystal boundaries have been eliminated by crushing and the fractures developed are filled with secondary quartz of the groundmass. The other feldspars are albite and microcline, occurring as small broken fragments. Quartz as an original mineral is present in small amount. Apatite and orthite are accessory. Chlorite appears as a secondary, in flaky patches and in stringers, conforming to the structural alignment. Epidote and calcite also appear in the groundmass as secondary. Hematite occurs as grains by itself and associated with chlorite, in the groundmass. The groundmass is composed of secondary quartz, crushed feldspar fragments, and secondary minerals with structural alignment, breaking through the smaller phenocrysts and going around the large orthoclases. The rock has apparently been in a zone of considerable crushing.



GNEISS

A band of dark green felsitic rock near the top of the peak (24B) was found to consist of a mass of shattered granular feldspar crystals, orthoclase being largest in point of size and albite in number. The spaces between the fragments are occupied by a groundmass of minute feldspar fragments, epidote, green colored biotite, chlorite, hematite and some quartz. Apatite is accessory and is also found included in orthoclase and albite. There does not appear to have been any invasion of the rock by secondary quartz, the usual prevalent condition in the gneiss, and the only alignment is that of chlorite shreds. Hematite appears only as grains in association with chlorite and epidote. The color of the rock is due to the large amount of biotite, which has all the characteristics of a secondary product. The rock appears to be a severely crushed and compressed phase of the gneiss, but was not penetrated by the quartz invasion which the rock mass generally appears to have undergone. The granular nature may, however, indicate it to have been an old sediment completely metamorphosed and involved in the gneiss. Other occurrences (Slide 2 and 39) suggest the same interpretation.

A sample of gneiss (16B) at Planet, near the river, was found to consist of orthoclase, microcline, plagioclase and a little quartz as primary minerals. These have all been much fractured and the intervening spaces filled by a groundmass of fragments of the primary minerals and introduced quartz. There is no particular alignment of these minerals. Apatite is accessory. Chlorite and epidote occur in the ground-mass and in veins crossing the section. These veins contain for the most part secondary quartz. A few grains of hematite appear.

When the results of all the slides examined are taken into account there are several observations worthy of remark. In regard to the feldspars they show the relationship that when microcline is present in largest amounts albite is next, with orthoclase following third; when the last predominates, microcline retires to third place, being exceeded by albite. Seldom does the plagioclase exceed in amount the combined amounts of orthoclase and microcline. No hornblende was found in any slides examined and very little original biotite. The low amount of primary quartz and original ferromagnesian minerals which are now probably represented by chlorite and secondary biotite, is also to be noted. While albite appears to be the prevailing plagioclase, oligoclase undoubtedly also occurs.

If the uncrushed portion of (17) is to be considered as approaching the original composition of the rock and this taken together with the above facts, the rock can be classified as a soda granite or as a quartz monzonite. As, however, neither term exactly fits the rock's composition, and as the present state is one resulting from severe crushing and the invasion of quartz, the rock is perhaps best termed a granitic gneiss. For brevity, and confroming to the earlier usage, the rock will be referred to as a gneiss. The rock is interpreted as a high soda phase of the general basement complex.

Precambric Dikes:

Numerous large pegmatite dikes occur in the foothills and some are to be seen near the highest peak. Shearing of the basement seems to have been later than some of these intrusions, as frequently banded structure in the basement is folded by compressive forces acting at right angles to the pegmatite intrusion, which remains undisturbed.

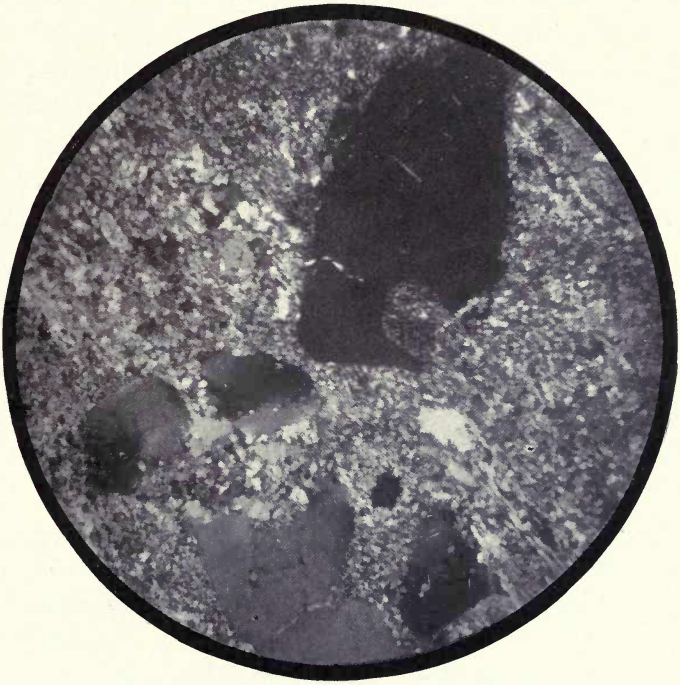
Precambric Sediments:

Throughout Western Arizona, quartzites, schists and metamorphosed limestones are reported lying unconformably upon the basement. General evidence has assigned them to the Precambric. In this area are several prominent foothills capped with such limestone; its dark brown color causing these hills to stand out conspicuously against the other colorings of gray and red. Such is the case at Brown Mountain, near Osborne's Well and at Planet. They, however, possess portions that are gray and near the Billy Mack Mine the greater part of the limestone is of this color. Megascopically the rock is exceedingly fine grained and either gray or pinkish in color. It is often siliceous, discolored by hydrous iron compounds, inclusions of hematite and covered with desert varnish. Under the microscope the purest specimens were found to consist of a mass of fine individual calcite grains, which are colorless and show polysynthetic twinning, crossed twin lamellae and well defined cleavage. Some of the crystals are broken and fractured, but they are the exceptions. A very few inclusions of light brown ferruginous alteration products occur. A more detailed petrographic and structural description will follow in the discussion of ore deposits.

While the above limestone is the most conspicuous, there occur also a few remnants of exceedingly pure limestones and dolomites, included within the basal gneiss. These beds are intimately associated with the hematite deposits. In the hand specimen they are either white or pink in color and highly crystalline. Some phases (7B) are semi-translucent marbles, composed of small oval grains of calcite, with their larger diameter parallel to the thin bedding plane, which is 1 to 1½ inches wide. Muscovite has developed along these planes. In the case of the dolomites, the crystals are quite large, show well defined and universally developed twinning and frequently little or no disturbance. Many cases, however, show considerable fracturing with bowing of the dolomite crystals and introduction of calcite into the section.

The Precambric Rhyolite Porphyry.

East and west of Mineral Wash along the south wall of the Williams, in contact with the basal gneiss, is an intrusive sheet of sheared rhyolite porphyry. At the contact are several inches of brecciated material, indicating overthrust faulting along the line of contact which has a general dip to the west or southwest, with the porphyry striking in a northwesterly direction. This rock extends south from the river almost three miles and forms the greater part of the foothills which separate the river from the east and west wash to the north of Planet Peak, and is later than the gneiss and probably later than the metamorphosed sediments. It has suffered severe metamorphism along with the above rocks and is consequently assigned to the Precambric. In the field it could easily be taken for a schistose development of the basal gneiss, and it also has the same general gray color. A well developed platy structure is exhibited and at right angles to the structure, joint planes.

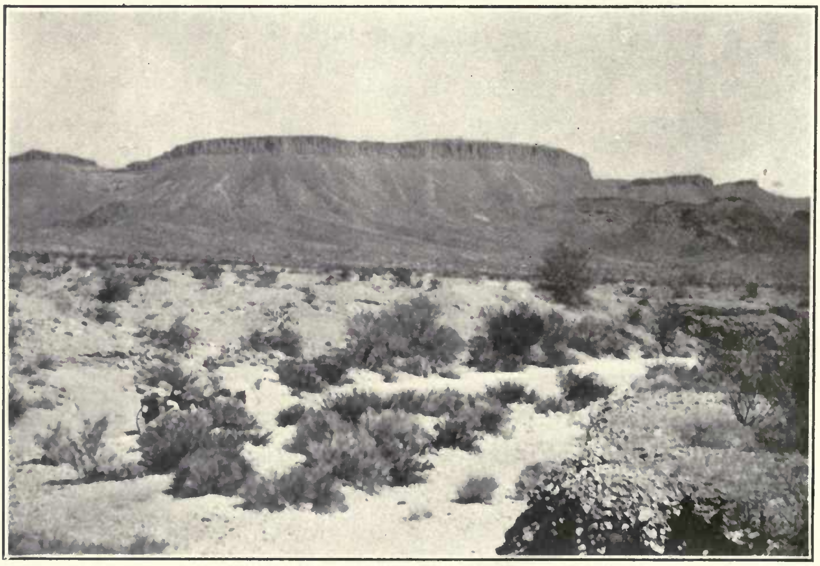


PRECAMBRIC RHYOLITE PORPHYRY

Under the microscope the slides (26, 26B; 28, 35B) gave uniform results. Quartz, orthoclase and plagioclase phenocrysts are the only original minerals distinguishable. The quartz is present in considerable amount and together with the orthoclase has been partially reabsorbed by the groundmass. The plagioclases are as a rule badly altered but retain their twinning planes. There has been crushing of these minerals, as evidenced by fracturing. The groundmass makes up at least half the rock. It is micro-granular and consists of quartz, sericite, flaky muscovite and calcite; the groundmass forming large embayments in the quartz and arranged in swirling lines around the phenocrysts. Hematite occurs in masses in association with colorless fresh epidote and calcite. The feldspars have all been altered to some degree. The absence of chlorite and the presence of only a very small amount of hydrous iron compounds are to be noted. The persistence of large amounts of original quartz, the high percentage of the groundmass and its corrosive action are features entirely absent in the basal gneiss and are considered as of sufficient distinctiveness to differentiate it from any magmatic phase of the basement gneiss.

Quaternary Temple Bar Conglomerate:

The great thickness of stratified beds displayed in the Williams Canyon has been correlated by Lee[1] with the Temple Bar conglomerate, which he has named from its exposure at Temple Bar near the mouth of the Virgin. Along the Williams River and south it rests unconformably either on the basal gneiss or the rhyolite porphyry just described. Where it forms the north wall of the Williams its basal portion consists of large boulders of gneiss and quartz firmly consolidated by a matrix of sand and gravels. Higher up, the beds are well stratified sands more or less firmly consolidated. They are as a rule buff or pinkish in color. They frequently extended beneath the valley floor. The south wall shows them resting on the basal gneiss, well stratified, reddish in color and pinnacled by wind erosion. South of the mouth of Williams River the steep sides of the mesa are carved from these detrital beds, and south of Giers Basin the trail mounts over the basal part, which is a well-consolidated hard red sandstone. In Mineral Wash



TEMPLE BAR CONGLOMERATE—(4 miles S. of Williams River) the canyons, formed at some earlier time in the rhyolite-porphyry contain residua of these beds, which have resisted recent erosion. Three miles south of the river at the junction of Mineral Wash and the Wash to Bouse, these beds are again prominent, but of no great height, lying horizontally, as usual, with exceptions noted later on; and the basal red part is seen also just north of the Junction of the two washes and east in the Wash to Bouse, just north of Planet Peak, where the basal part is badly tilted. North of the Williams drainage divide, red sandstone covers the basin, rising sharply at the side of the valley from their horizontal position. They are mostly red in color, but it appears that their original color was gray, as displayed in many portions of the beds. Here the steep sides of the mesa consist of detrital beds similar to those in the south wall of the Williams River. There is a suspicion of a disconformity between the beds at this place, which if established would probably make these beds equivalent to the Greggs breccia, which Lee notes as overlain disconformably by the Temple Bar. Factors introduced by recent vulcanism, however, vitiate any conclusions on this point.

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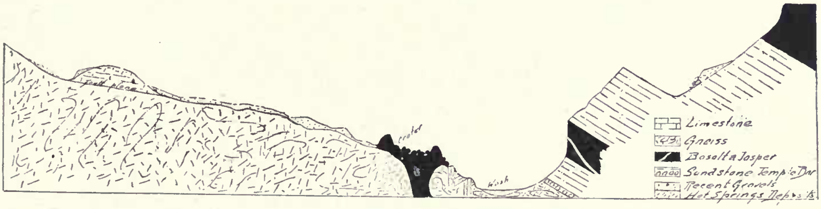
[1] Bull. U.S.G.S. 352, p. 54.

Just west of Brown Mountain and north of Osborne Well, there is a hill of some prominence formed of red sandstone with its bedding dipping 45° to the southwest. These beds lie on the basal gneiss, with a conglomerate base and are in the immediate vicinity of a volcanic crater. In Osborne Wash the detrital beds are again seen, rising some 60 feet from the bed of the Wash and show effects of wind erosion and bad land topography. The beds are dull red, stratified and fairly well consolidated, and represent the upper portion of the conglomerate.



IDEAL EAST AND WEST SECTION NEAR BROWN MT.

Two thin sections were examined of the basal portions of the detrital formation, one at Red Mountain (7) and one four miles to the north near the drainage divide. No. 7. The section consists of large fragments of fresh microcline, orthoclase, plagioclase and quartz. These fragments are cemented together by a groundmass consisting of minor fragments of calcite and sericite. Hematite is present in aggregates and has altered on the edges sufficiently to produce dark brown alteration products, which fill all interstitial spaces and cleavages in the rock and account for the color. The rock is arkose.

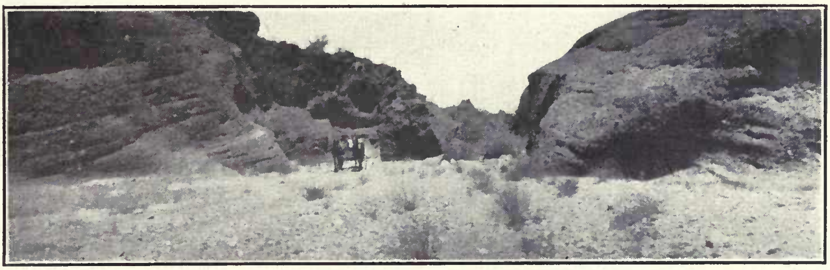
No. 19. Rock is composed of large fragments of plagioclase, microcline, orthoclase and quartz, equal in amount to all the feldspar fragments. The feldspars are fresh, excepting the plagioclase which is frequently altered to sericite. One quartz grain includes a fair sized plagioclase grain. Biotite, with basal cleavage, chestnut brown color, and strong pleochroism, occurs in lath shapes and shreds arranged around minerals in the matrix and around altered feldspars. Some flakes of chlorite, shattered grains of titanite, a few crystals of apatite, several fragments of diabase, with small lath-shaped feldspars occur. Hematite is in irregular masses, veins and stringers. The matrix is made up principally of small fragments of feldspars, mostly altered; sericite aggregates and fine grained quartz. The minerals bear no relation to one another and the rock is a typically fragmental one. It is to be noted that these two sections are composed of fragments of the minerals which make up the basal gneiss and retain even the peculiar relationships of the feldspars. This would seem to indicate that the materials were derived originally from the Buckskin Mountains and represent detrital fans. Although the rocks are fragmental in character, the size of the fragments and their decided angularity of boundaries, show that they have not been subjected to long transportation. The diabase fragments are the only evidence observed of these rocks occurring in this area earlier than the Quaternary. It should be added that the sample (19) was taken near the contact with gneiss.

These detrital beds slope decidedly south from the Williams. Local tilting in these beds, due to intrusive masses, will be mentioned later. The maximum exposure of the beds is near the Williams where they are at times from 500 to 900 feet thick. At Red Mountain the tilted sandstone represents a little over 600 feet of once horizontal strata. It would appear from field observations that the detrital beds once extended well up the flanks of the Buckskin Range.

The red basal sandstone contains concretions and other forms which are harder than the sandstone and stand out from weathering. These proved to be made up of angular fragments of quartz, fresh plagioclase and microcline. Shreds of biotite arranged in same general direction are abundant. Hematite is in masses, with no particular arrangement.

Rhyolite Tuff:

Succeeding conformably the Temple Bar conglomerate is a bed of rhyolite tuff. It varies in thickness from fifty to five feet, but consistently caps the Temple Bar throughout the area south of the Williams. It is fawn colored and well stratified; its bedding was nowhere noted disturbed. Near Osborne's Well in close proximity to a crater it seems to have its maximum development and farther to the west in Osborne Wash, close by to where the road turns off to Parker, and at an elevation of 550 feet, it grades into a more calcareous bed having a thickness of 44 inches. At the contact of this stratum with the underlying conglomerate fossils were found.



TILTED TEMPLE BAR CONGLOMERATE—MINERAL WASH

Megascopically the tuff is composed of fine grained material with frequent patches of white volcanic glass. In the Temple Bar conglomerate near its base, at the head of Mineral Wash, are three feet of white tuffaceous rock, between conglomerate beds. It is well bedded, more so than the conglomerate, and represents some earlier volcanic action with apparent deposition under water. It shows also in the sandstone two miles to the south. The volcanic tuff (60) under the basalt near Osborne's Well has a groundmass of glass, with flowage structure. Within the groundmass are partly formed crystals of green augite, small needles of plagioclase and amphibole. Quartz in grains and masses are numerous and quartz frequently shows well developed concentric calcedony crystallization. Numerous grains of hematite are altered to red iron compounds.

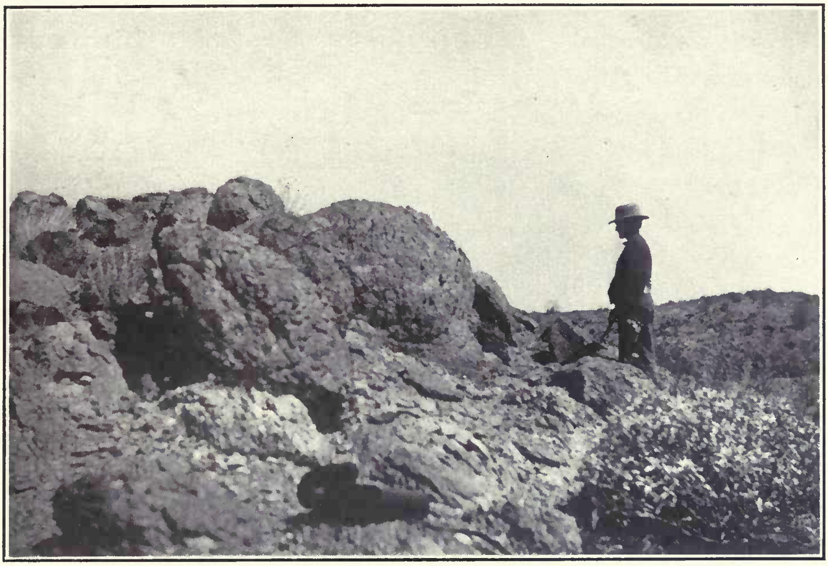
The white (62) granular bedded material, between beds of conglomerate, occurring in Mineral Wash, contained grains of quartz, altered feldspars, augite and a few iron alteration products. No groundmass was obtainable in the slide and the rocks is probably an aggregate of volcanic materials. In the same locality, tuff stands vertically between the contact of quartz porphyry and rhyolite porphyry, and (61) consisted of a gray felsitic groundmass, with areas of glass, which contain small needles of feldspars and grains of hematite with alteration products. Complete small crystals of albite have been formed in the gray groundmass, and some larger fragments are altered slightly to sericite. A few grains of green augite and shreds of green biotite in association with altering feldspars occur. Quartz as grains and segregated masses are present in the gray groundmass.

Quaternary Basalts:

The basalts form one of the most prominent features, and all seem either to be contemporaneous or later than the detrital beds into which they have become intercalated, or have formed a capping. There is evidence that some of them were poured out at the same time the detrital beds were being deposited. In thickness the basalt varies from 800 feet to 400 feet, according to its location and character. In the vicinity of the two crater areas near Osborne Well they have been intercalated into the basal part of the sandstone, but the basalt under the rhyolite tuff is probably earlier than those undisturbed beds. Along both walls of the Williams River necks and dikes penetrate through the gneiss and through to the top of the detrital beds capping them with basalt and as a rule also intruding sheets. In places these sheets seem to have been outpoured and later sediments have been laid down on them. Tilting of the strata is noticeable in the immediate neighborhood of the necks and dikes and also lateral baking. Both along the north wall and in the wash north of Planet Peak there seems to have been recent lateral slipping of basalt blocks, leaving them lying pitching at an angle of from 15° to 20° to the southwest.

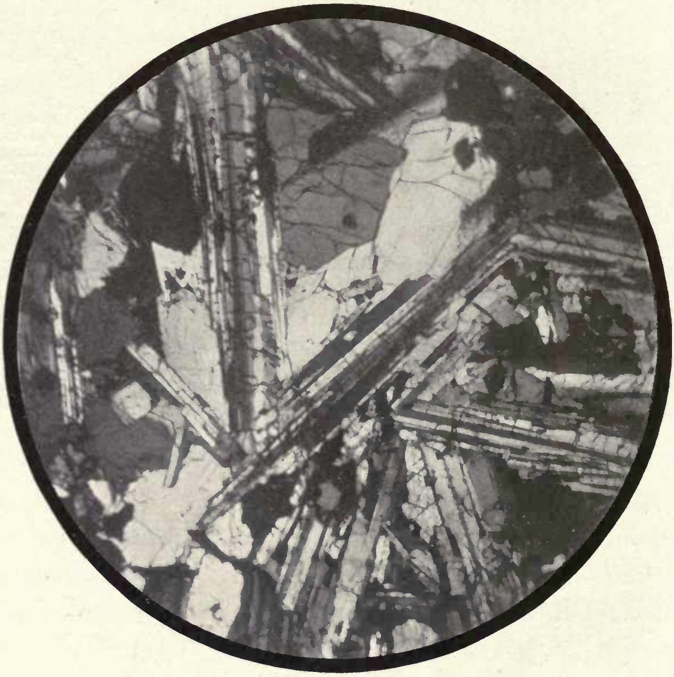
Near Osborne Well is a considerable area of extinct craters; one quite close and another three miles to the north, near a hill of sandstone. At the latter place the crater has broken through the overlying sandstone tilting it to an angle of 45° to the southwest and converting the sandstone on the flanks of the crater into distorted masses. The sharp upward curve of the sandstone on both sides of the valley to the north is probably due to some such volcanic agency, as the angle of slope from the horizontal position of the beds in the middle of the basin is too great and the distance too short to allow of the angle of the beds being due to confluent fans from the east and west. In the wash north of Planet Peak the sandstone pitches steeply with an intercalated bed of basalt, but volcanic necks are here, too, in the vicinity. At Osborne Well it should be noted that except for a gap through which a wash has been cut, the basalt practically exists from the crater and continues a part of the mesa. Near the crater it shows column structure with the usual hexagonal jointing.

Within the crater there are masses of convoluted forms resembling huge cabbages piled one on another, lithological representatives of the volcano's dying action. A thin section (4) from one of these masses showed the rock to have a trachytic structure, and plagioclase the most abundant mineral. These feldspars are mostly needle lath shaped, some of which are albite, with their long axes arranged in the same general direction. Large crystals are frequent and all are fresh. The twinning is narrow and extinction angles indicates them to be albite. Colorless olivine crystals, showing no pleochroism, extinction parallel to cleavage and alteration products green and brown in color, are frequent. There is also some fresh augite and a few plates of brown biotite. The groundmass is made up of minute lath-shaped plagioclase, hematite grains, sericite and calcite. The rock cooled under intermediate conditions of temperature. A part of the heavy flow just by (8) showed holocrystalline texture, the rock being composed of large lath-shaped plagioclase crystals, arranged with their long axes in the same general direction, but being cut at various angles by smaller laths, which are completely formed, the larger ones not being so. Both, however, are badly altered and corroded by hematite. Olivine occurs in considerable amount, but segregated in groups. The crystals are large, colorless or tinged pink, with pronounced cleavage cracks filled with black alteration products which also surround the crystals. No augite is present. Chlorite and apatite occur in small amounts, while hematite appears as grains and elongated masses, filling veins, cleavage cracks and interstitial spaces which are also occupied at times with sericite and calcite. Dark brown and red iron alteration products are abundant.



CONVOLUTED BASALT FORMS—IN CRATER

Almost west of Osborne Well about eight miles, Black Peak rises some eleven hundred feet from the desert. A large part of this peak is composed of a bluish gray diabase which was outpoured before the capping of basalt. This is shown around the rim of the small crater just to the northwest, where the diabase dips toward the southward at an angle greater than the dip of the later basalt. This biabase (34B) has a well developed texture. Long lath-shaped feldspars, with albite twinning, average extinction angle 53°, and index of refraction exceeding that of orthoclase are anorthite. Numerous laths of labradorite with extinction angles of about 27° also occur. Augite exceeds olivine and is almost colorless, fresh and in well formed laths. Olivine is present in an amount only slightly below that of augite and both have accommodated themselves into the triangular spaces between the feldspars, although occasionally feldspars project into the pyroxene. The olivine is colorless and fresh for this mineral, containing only slight amounts of greenish and red alteration products in its cleavage cracks and around its boundaries. Hematite is next in amount and usually associated with the above two minerals. A little epidote occurs, as does a host of long slender apatite needless, included in the original minerals.



DIABASE—BLACK PEAK

The basalt capping has withstood weathering on the surface better than the diabase. It, however, frequently is coated with calcite, which fills its amydaloids, and near the top of the peak there occurs a white calcareous, siliceous material between the malapi blocks, which constitute the broad top of this peak. This basalt (2B) proved to have also a diabasic texture of medium sized labradorite laths, the large crystals showing zonal growth and attack by groundmass, with olivine forming subsequently in the breach. Large numbers of inclusions are in the feldspars. Olivine is next in amount, well crystallized, and not badly altered, except for the presence of an orange red alteration product in its cracks and on its surface. Hematite is throughout the section as grains and needles; also some patches of fine-grained calcite. The rock is quite fresh. A sample from a narrow long dike north of Kohan's ranch on the Williams River gave these results (12B). Phenocrysts of labradorite and augite are surrounded by swirling bundles of plagioclase needles. The groundmass also contains calcite and dark red alteration products. Some calcite approaches in size the other minerals and shows its distinctive twinning. Large feldspars show zonal growth and reabsorption.

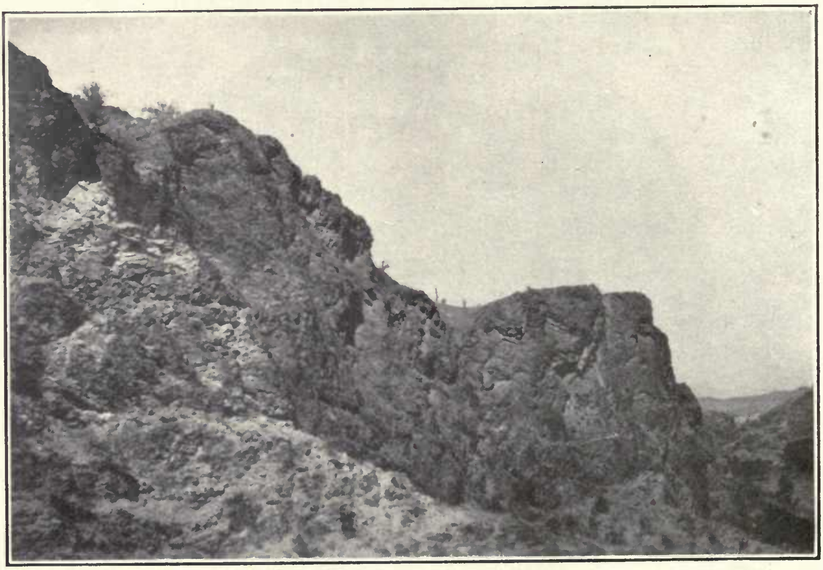
These olivine basalts are typical of those of the southwest and present no unusual features, except as to the determination of their consistent constitution.

Quaternary Rhyolite Porphyry:

This rock is the most interesting as regards the economic side of the district. It is confined to the south side of the Williams River from

QUATERNARY (?) RHYOLITE PROPHYRY

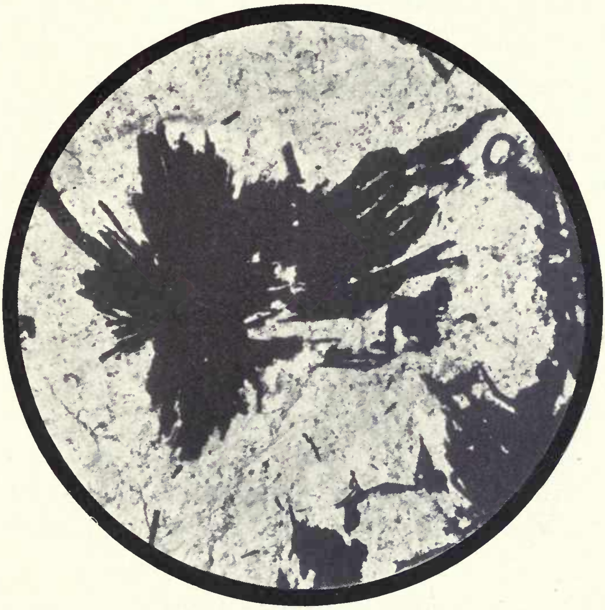
which it extends south three miles with the exception of several prominent occurrences on the north side. It appears to be later than the detrital beds but whether later or earlier than the basalt is not so evident. It has the character of an intruded sheet or a huge dike, coming through and overlying eroded Precambric rhyolite porphyry and gneiss and appears to have tilted and metamorphosed the detrital beds. In the field it is the characteristic red rock which caps most of the foothills south of the Williams River, which has cut its channel through a mass of it. In the hand specimen the porphyry is compact with numerous quartz grains showing and when not red its unoxidized portions are dark greenish to blackish in color. Samples (22, 23, 24, 25, 27-29B) gave uniform results. Large phenocrysts of quartz are the most conspicuous feature. They have been severely attacked by the groundmass and large embayments have been corroded in them; slight fracturing is shown. Orthoclase has been acted upon in a similar manner, in instances, but as a rule it is badly altered, or changed to sericite, and only a semblance of its former condition remains. Chlorite is present in fair amount in association with hematite, while apatite crystals are numerous. A few remnants of biotite altered to iron hydrous compounds occur and patches of hematite are conspicuous. The groundmass, which represents 50-75% of the rock, is composed of microquartz, which has accomplished the corrosion; and also sericite and a large amount of iron hydrous compounds, which give to the rock its color. Considerable shearing is often evident. This rock will be referred to again in the discussion of ore bodies.



QUATERNARY RHYOLITE PORPHYRY IN CONTACT WITH PRECAMBRIC RHYOLITE PORPHYRY—WILLIAMS RIVER

Hot Spring Deposit:

More recent than the basalt is a peculiar, angular formation, which form patches on the gneiss foothills, the high dipping sandstone of Red Mountain, and as flat benches adjoining the basalt slopes. It contains fragments of the rock above which it lies and at its base are frequently large rounded masses 2.5 feet in diameter with these fragments arranged in more or less parallel arrangement or indiscriminately. The cement is calcareous and siliceous and the only satisfactory explanation, covering all its peculiarities, is that they have been formed by hot springs coming up through the formations and representing the dying phases of the recent volcanism so manifest in the district.



HEMATITE IN HOT SPRING DEPOSIT

A thin section near Brown Mountain gave these results. (14) A groundmass of small calcite grains surround fragments of microcline, plagioclase, augite and quartz. Chlorite, epidote, zeolites, apatite and titanite are present in small amounts. A few muscovite shreds are to be seen. Hematite occurs in large masses, often with a crystalline radial structure, and iron hydrous compounds are present in fair amounts. In another instance (38) where the specimen was not massive, the groundmass of calcite surrounds larger calcite grains, which show twinning. Lines of flowage are pronounced. Quartz is scattered throughout the groundmass as rounded and angular grains, sometimes of large dimensions. It is also present in wide bands, with direction parallel to that of the calcite grains; it may cross the groundmass. Hematite is scattered as grains and large masses, surrounded by yellow and dark brown alteration products.

GEOLOGIC HISTORY.

Precambric:

In discussing the historical geology of any part of Arizona, it is necessary to refer to the section revealed in the Grand Canyon, where erosion has exposed the rock formations in a sequence nowhere else exhibited in the State. The Archean is there exposed, conspicuously base leveled, as is apparent to even the casual tourist who descends to the rim of the lower gorge. A pre-Algonkian peneplanation still exists in the eastern part of the canyon, but it is a post-Algonkian erosion plane, developed to a less degree that has beveled across both Algonkian and Archean rocks; and presumably it is this later base leveling which extends west and has been traced by W. T. Lee as far south as the Juniper Mountains, about latitude N 35° along the Grand Wash Cliffs.

No mention has been noted of base leveling observed in the granite and gneiss forming the mountains west of the Grand Wash Cliffs, although these rocks are supposed to be the same as the granite underlying the Paleozoic strata, exposed in the western escarpment of the Colorado Plateau. The granite mountains of Central Arizona, the Bradshaws, show no Archean peneplanation. Ransome[1] reports effusives overlying "an uneven surface of granite" in Eldorado Canyon, which is on the west side of the Colorado at about latitude N 35° 40′. Bancroft,[2] however, has observed the gneiss and granites of the southern ranges to have been partly base leveled and that the numerous intrusions of pegmatites, hornblendic granites and aplites occurred before regional metamorphism and considers the complex, Archean in age. This base level would appear to be one of pre-Algonkian age. No well developed base leveling was noted in the Buckskin range. The microscopic similarity of the basal gneiss has been discussed and excepting for the hornblendic gneiss, the gneiss of the Buckskin Mountains could only be differentiated on account of a higher soda content.

Unconformably upon the leveled Archean in the Grand Canyon is 11,950′ of Algonkian. To the south in the Bradshaw Mountains, Jaggar considers that 7000′ of Algonkian represented by the Yavapai schist and Crooks complex has been intruded by the Bradshaw granite after pre-

[1] Ransome, F. L. Bull. 303, U.S.G.S. p. 68.
[2] Bancroft, Bull. 451, U.S.G.S. p. 23, 34.

vous folding of the schists. Lee observed in Virgin Canyon and in the Granite Wash Cliffs, near Harrisburg "Metamorphosed quartzites, argillites and limestone . . . faulted, tilted and more or less included as blocks within the granites and gneisses" which he considers as Precambric. According to Lindgren, in the Clifton Quadrangle, the Pinal schists are to be correlated with the Algonkian of the Grand Canyon, and that Precambric granites were intruded into these schists.

The above facts indicate that some orogenic movement effaced an extensive Pre-Algonkian base leveled surface south and west of the Grand Canyon and was accompanied by intrusions of granite and gneisses into Algonkian sediments layed down upon an Archean basement. Van Hise[1] believes that the Algonkian in general represents a time longer than that of the Paleozoic. It is difficult to comprehend that during such a lapse of time this region should have remained entirely quiescent and also that deposits of Algonkian age were not laid down in western Arizona as they were so extensively in the Grand Canyon, as the Grand Canyon series and to the immediate east as the Yavapai schist.

In the Buckskin Mountains, the oldest rocks are a few patches of pure crystalline limestone and pure dolomites, included within the gneiss. They nowhere are exposed except as limited outcrops, dipping at various angles, from the vertical to 18° or less. Weathering has not affected them, except in places to cause them to disintegrate. Their age is indirectly testified to by their extreme purity and the high degree of dolomitization, which also signify that they were at some time deeply buried and subjected to enormous deformation. This is further demonstrated by the excessive development of twinning in the dolomite grains. An analysis of the crystalline dolomite gave these results:

$CaCO_3$	53.32%	CaO	29.86%
$MgCO_3$	41.45	MgO	19.74

The ratios of its molecular proportions for the amount of CaO and MgO is 1.08 to 1.00, approaching nearly the ratio of 1:1, as in a pure dolomite. Iron is present and calcite was determined to have been introduced later into the rocks, along with the disturbance of the dolomite grains. No magnesite was determined, as such, under the microscope, and if present, was only so in minute grains. It is evident from the above that dolomitization was developed to a degree rarely noted in rock of recent deposition. A semi-translucent white marble in close proximity to the above sample gave these results:

$CaCO_3$	93.95%	CaO	52.62%
$MgCO_3$	2.05	MgO	.97

At the bottom of a 100′ incline, following at 18° a bed of dolomite, a sample was taken. At this point the stratum would be about 30′ beneath its outcrop and have roughly 50′ of gneiss for a hanging wall. The bed has been followed down some 200′ further. The sample (29) proved to consist mainly of large dolomite and calcite grains, with twinning conspicuously developed. Dynamic forces had shattered the rock, and calcite was introduced. No impurities of note were developed. Four grains of calcite had similar forms, which cannot be accounted for on a crystallographic basis or by any structure developed in the rock. The well defined annular form seems only explainable as fossil structure, resembling the cross section of a crinoid stem. The four forms differ only in size.

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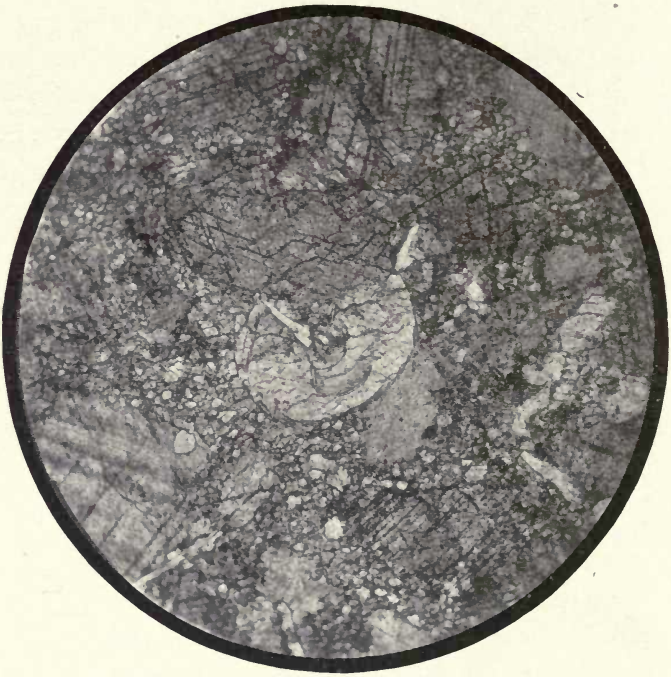
[1] Van Hise, Bull. U.S.G.S. 360 p. 35.



ORGANIC REMAIN IN PRECAMBRIC DOLOMITE

If this conclusion is correct, it signifies organic remains in a crystalline dolomite undoubtedly included in gneiss. Dikes of sandstone,[1] carrying a Cambric fauna are known to occur in the Precambric gneisses of Sweden and it is considered that a transgressing Cambric sea filled fissure in the gneiss with sand. A similar interpretation has been employed by Wolff[2] to explain a quartzite occurring in Precambric limestone in New Jersey. If such an origin is to be assumed for a later fauna included within an earlier rock, it would seem necessary, as in the above cases, that the fissures be filled with sandstone or some other clastic material, otherwise than that which would yield a pure limestone or dolomite.

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[1] Hogbom, A. G. Precambrian geology of Sweden. Bull. Geol. Inst. of Upsala, Vol. X, (quoting A. Gavelin).

[2] Wolff & Brooks, 16th Annual Report, U.S.G.S. Pt. 2, p. 454.

At Brown Mountain the gneiss is separated from an overlying later, metamorphosed limestone by a fault contact. This limestone, with its prevailing dark color, is to be seen also at Planet and in numerous other localities. At Planet, Bancroft[1] reports it separated from the eroded gneiss by 30′ of conglomerate and in other places, the sedimentary complex, he has noted, has a much greater development, with quartz mica schist as the oldest. In other instances he has observed as much as 200′ of quartzite overlying the gneiss and succeeded by limestone, also a thin layer of dolomite with a magnesia content of 20.59%. It appears that the sedimentary strata overlying the gneiss are of some considerable development and have undergone metamorphism in general. The limestone as observed near Planet Peak, Planet and Brown Mountains and Billy Macks, has characteristics in the field and under the microscope entirely different from the older metamorphosed dolomites. The former limestone, at its purest, crystallizes as an aggregate of fine calcite grains, which show little or no disturbance. It has also undergone metamorphism but little dolomitization as shown by the analyses collected by Bancroft.[1]

PRECAMBRIC LIMESTONE—BROWN MT.

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[1] Bancroft, Bull. U.S.G.S. 451, p. 27.

Sample of Limestone at Planet:

CaO	44.63%
MgO	2.11

Both at Planet and at Brown Mountain very small patches of the limestone were noted faulted into gneiss, quite close to the main limestone mass, and the faulted pieces were exactly similar under the microscope to the limestone of the main mass. Microscopically, chemically and in its field relationship it is entirely different from the older limestone and it seems highly improbable that the one is related in any particular to the other.

That the basement rock of western Arizona has suffered regional metamorphism is not readily disproved. Lindgren[1] considers that "there has been no regional metamorphism in the Cordilleran region since Precambric time, except along the Pacific Coast in California, Oregon, Washington and Northern Nevada." If consistent development of cleavage and gneissoid structure over a great area is a criterion of Precambric age, the basement fulfills such requirements and also eliminates any possibility of the basal gneiss having been intruded into sediments of later than Precambric age. There is no known occurrence of regional intrusion into the Paleozoic strata of Arizona and there is no evidence that the Buckskin Mountains have been intruded into such strata, on such a scale as to have engulfed strata of great thickness, leaving to-day only included residua within the mass, with later metamorphosed sediments resting unconformably upon it. It appears reasonable that the Buckskin Mountains and perhaps other ranges in the Basin region represent an intrusion into Algonkian strata similarly to what has taken place in the Bradshaw Mountains to the east, where the granite intrusion has completely involved seven thousand feet of Algonkian strata; and that the limestone included within the gneiss of the Buckskin Mountains is of Algonkian age, as it contains organic remains. That a disconformity exists between the gneiss and the succeeding metamorphosed sedimentary complex has been fully demonstrated by Bancroft.

It is interesting to recall that the fossils found in the Algonkian of the Grand Canyon series, occur in the upper Chur formations and that a disconformity exists between the Chur and Unkur, the lower portion of the Algonkian. Also that limestones are found in both divisions.

There seems, however, not to be sufficient facts which would justify a correlation between the Algonkian of the Grand Canyon and the older limestones, included within the gneiss, of Yuma County. It is also impossible to assign any definite age to the sediments unconformably overlying the gneiss. No fossils have been found in them and they are nowhere overlain by beds of known age. Throughout the paper, conforming to previous interpretations, they are called Precambric in age.

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[1] Bull. U.S.G.S. 507, p. 10.

Intrusives:

Numerous pegmatitic intrusives penetrated the gneiss before metamorphism took place, but the most noteworthy and extensive of these igneous intrusives is the rhyolite porphyry, which forms the core of many of the foothills just south of the Williams River. This rock has passed through the same metamorphic history as has the gneiss and is not readily distinguished from it in the field. It possesses all the evidence of having once been in the zone of fracture and to have been severely sheared. Owing to its degree of metamorphism it is believed to be an intrusive of Precambric age.

Paleozoic and Mesozoic:

Undoubted Paleozoic strata are not known in Arizona west of the Grand Wash Cliffs, although they are supposed to have also probably once extended across Western Arizona, owing to their prominent development in the western escarpment of the Colorado Plateau, where a generalized section of strata later than Algonkian shows a thickness of over 13,551 feet.[1] About all that is definitely known of post-Algonkian time is that the first faulting which took place in the Tertiary left the western part of Arizona at a greater elevation that the country to the east and that subsequent faulting which terminated in the development of the Grand Wash Cliffs hoisted the Colorado plateau some 6,000 feet above the Basin region, according to the well known interpretation of Captain Dutton. The Basin region apparently had been completely denuded before the Tertiary intrusions and outpouring of lava occurred in the northern portion, as no Paleozoic strata are reported underlying them, except a few possible remnants mentioned by Schrader and previously referred to. As the base of the Temple Bar in Yuma County is composed of rock constituents similar to the basement, it would seem that the removal of the sedimentaries had been complete some time previous to the formation of the Temple Bar conglomerate. It appears also that the gneiss had a drainage developed on its surface previous to the succeeding deposition, but this probably was formed in the Tertiary period.

Tertiary and Quaternary:

The Tertiary appears to have been a period of degradation and its antithesis. It is considered by those who have given much time to its study to have also been a period of uplift in western Arizona accompanied by volcanism in the northern portion. All that can be definitely said for northern Yuma County is that on the irregular and serrated surface of the basement was deposited the Temple Bar conglomerate, which has the aspects of a torrential or river deposit. These beds were originally gray in color and are to-day, except where more recent basalt intrusives have affected their original color. The evidence brought out by the microscope indicates that there was little iron content in the basal rocks and that the Temple Bar conglomerate is here essentially made up of the fragmental components of the basal gneiss and consequently when deposited were equally low in iron oxides or ferromagnesium minerals. It would appear also that the rocks have not been subjected to extreme aridity or semi-arid conditions for long. On the south side of Osborne Wash the Temple Bar is buff in color and over its rough surface a diabase has been outpoured. The surface, however, seems to have undergone some erosion before the diabase capped it. To the west of this exposure a thin bed of tuff 44 inches in thickness occurs near the top of the conglomerate. Above the tuff is some 30 to 40 feet of conglomerate, which is capped by basalt, a part of the flow which covers Black Peak and which lies on top of the earlier diabase, just referred to. In this tuff at the contact, with the underlying Temple Bar conglomerate,

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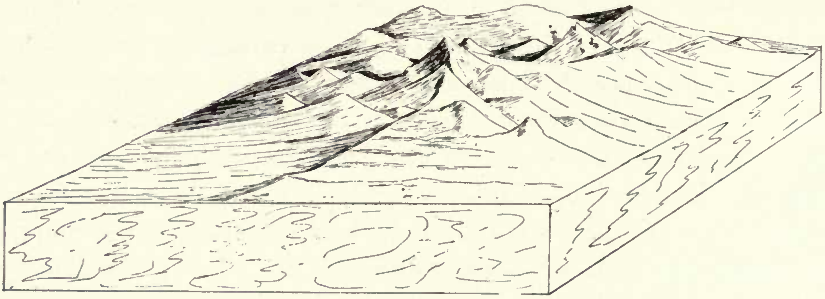
[1] Chamberlain and Salisbury (after Walcott), Vol. III, p. 574.

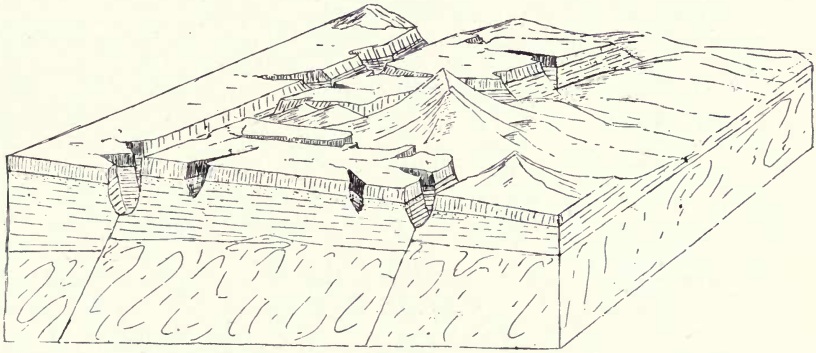


BLOCK DIAGRAM—PREVIOUS TO DEPOSITION OF TEMPLE BAR CONGLOMERATE—LOOKING EAST

FOSSILIFEROUS TUFF

fossils were found. It appears that the tuffaceous matter was deposited in a lake or pond and covered up the organisms on the bottom, as no fossils are found in the fine grained rock except at the contact. The presence of quartz and plagioclase and a few shreds of biotite and grains of hematite seem to indicate that the rock was formed from volcanic ash.

On a slab of the rock, taken from the contact, Dr. W. H. Dall of the United States Geological Survey, distinguished the gastropod Bittium and a probable young Corbicula. He also states that the Bittium is characteristic of brackish or saline waters, and that the state of preservation of the fossils would allow of their not being later than Pliocene. It is interesting to recall that Dutton[1] refers to the Pliocene lake Basin of the plateau country as exhibiting saline deposits, due to arid conditions. So far as known to the writer, the Temple Bar conglomerate has heretofore yielded no fossils. As the physiography of the Lower Colorado is superimposed upon the basalt capping the Temple Bar conglomerate, it would be of interest to find fossils of index character, which would allow of an age being assigned to these conglomerates, on a paleontological basis. Dr. Newberry[2] considered the detrital beds, near the mouth of the Williams River, as of Tertiary age.[3] Since then, W. T. Lee has provisionally correlated the same beds with the Temple Bar conglomerate by which they are referred to in this paper and considers them as having formed in the early part of the Pleistocene, subsequent to the formation of the Grand Wash fault, which he places in the middle Tertiary. Recent students of the Grand Canyon region have departed from the old Duttonian interpretation of the age of the Canyon cutting, favoring a more recent age. If, however, the Temple Bar is ever proven to be a Tertiary deposit, the interpretations of the older school of geologists may prove to be more correct.



BLOCK DIAGRAM—AFTER DEPOSITION OF TEMPLE BAR CONGLOMERATE AND OUTPOURING OF BASALT. EROSION IN ITS FIRST STAGE—LOOKING EAST

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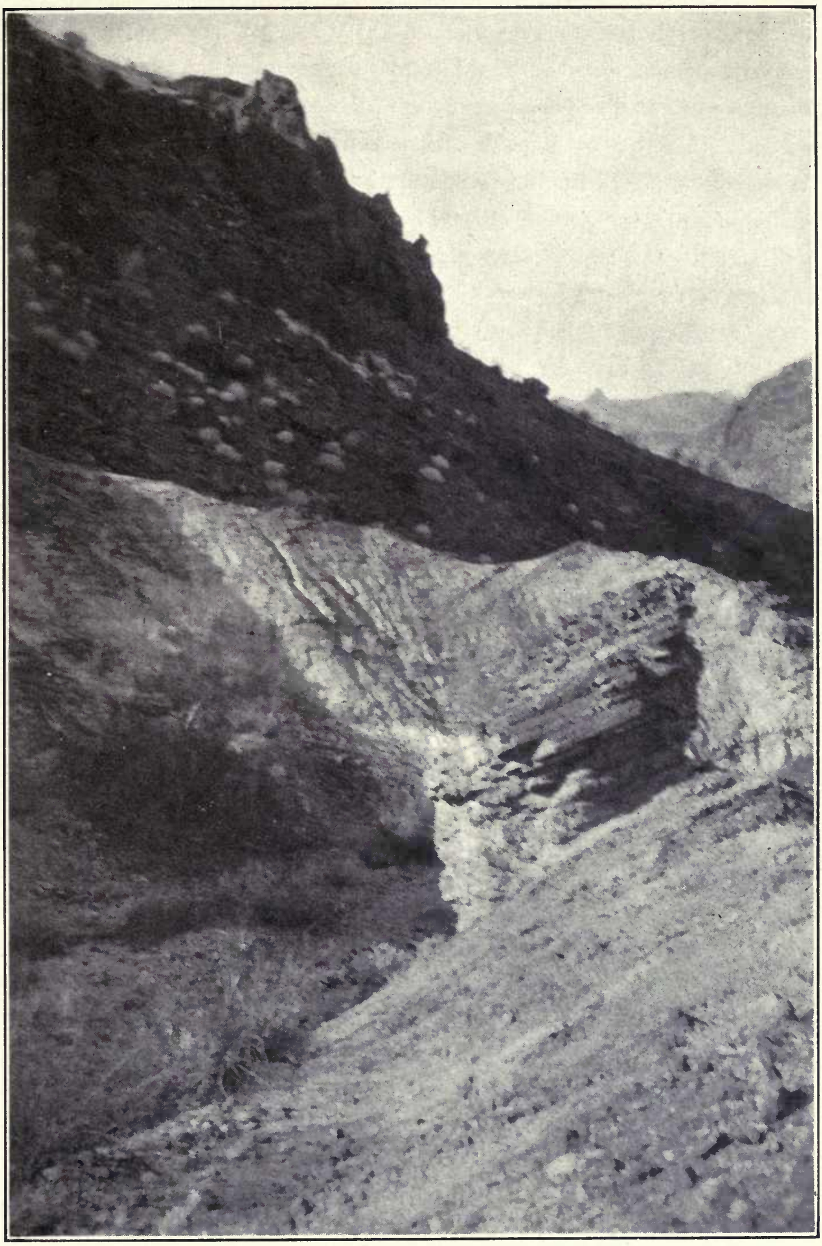
[1] Tertiary History of the Grand Canyon, p. 190, 1882.
[2] Colorado Exploring Expedition, Part III, Chap. 4, p. 29.

During the deposition of the conglomerate the region seems to have begun to show signs of volcanism, which manifested itself as contemporaneous layers of basalt and rhyolite tuff and later burst through and overspread the conglomerate and probably extended well up the sides of the Buckskin Mountains. These flows on the surface were probably accompanied by intrusions underneath, as indicated by the rhyolite porphyry exposed along the Williams River. It apparently has tilted the lowest members of the detrital beds, including those carrying a three foot bedded rhyolite tuff. The coarse crystallization of some of the minerals of the porphyry and the absence of glassy groundmass, necessitates the presence of an overburden, which was probably constituted by the overlying detrital beds and basalt flow. The beds near the contact with the intrusive are materially changed in character and where the older rhyolite porphyry is in contact it is frequently changed to sericite schist. Mineralization and quartz veins have accompanied the intrusive and a conspicuous fact is the appearance of large quantities of red oxides, in a country heretofore grey in color. This coloration, however, is only associated with this rhyolite porphyry or the detrital beds near the contact. This oxidation of the iron content seems to be a comparatively recent result, as unexposed portions of the rhyolite porphyry are not excessively red. That the tilting of the detrital beds is caused by the intrusion and not by any faulting is shown by their gradation into undisturbed horizontal position not far from the contact with the intrusive. Portions of the conglomerate are also frozen to the intrusive. Dr. Newberry[1] mentions that "Several lines of upheaval cross the river (Colorado) connected with a range of hills which crosses Bill Williams Fork (Williams River) a few miles east of the Colorado. The igneous axes of these lines of elevation are greenstone and granite. By them Tertiary rocks are thrown up into hills of fantastic outline and vivid colors."

The mountain ranges in the Basin have their axes conforming in direction to the escarpment of the Colorado plateau, but south of where the escarpment merges into the Acquarius Mountains, the Basin ranges have various directions. If these Basin ranges are consequents of the uplift of the plateau region, their formation must not have escaped some form of crustal disturbance. Lee[2] considers the Hualpais Mountains as probably the result of block faulting. No evidence of block faulting was noted in the Buckskin Range, except for the steep northern slopes near Planet Peak, which, however, seem to be the result of slipping of blocks along shear planes, which stand at a high angle.

[1] Colorado Exploring Expedition, P. III, p. 29.
[2] Lee, W. T. Bull. 352, U.S.G.S. p. 61.



TILTED TEMPLE BAR CONGLOMERATE—NEAR INTRUSIVE

Slickensides are frequently noted on the sides of these blocks. Erosional forces work very effectively when so aided by the natural habit of the rock, and the Buckskins' seems to be undergoing rapid deformation. Insulation is supposed to play a great part in rock disintegration in desert and semidesert regions. This may hold true in Yuma County, but the evidence is not so apparent. In the summer months, the rocks are probably heated to temperatures above 148°F. during the day, with lowering temperature at night, and by sudden falls of rain. A. E. Douglas has noted soil temperature as high as 148° in the Grand Canyon District. There is no data on the maximum and minimum temperature these rocks undergo during these months of high temperature. The following temperatures were observed during a part of January, near the Williams River, and are added merely as data, of a kind which is lacking in our desert regions:

Date.	Maximum.	Minimum.
December 31, 1912	63°F.	39
January 1, 1913	65	39
“ 2, “	66	46
“ 3, “	68	42
“ 4, “	68	42
“ 5, “	68	28
“ 6, “	46	22
“ 7, “	40	13
“ 8, “	52	16
“ 9, “	60	21

Faulting:

After the outpouring of basalt it is apparent that the country south of the Williams River has been tilted gently to the south. This is evidenced by the southern drainage on the basalt surface, almost from the northern wall of the mesa, and by the higher position of the basal conglomerate beds on the south side of the river. On the north side they frequently are below water level. It is probable that the parallel drainage lines, Williams River, Osborne Wash and Bouse Wash farther to the south are along the fault lines developed. The fautling, however, was not of any great magnitude and the subsidence must have been comparatively gentle.

The latest historical periods are represented by the detrital gravels, hot spring deposits, hot springs still in action, and the formation of sand dunes. The extinct craters, despite their low position are free from any accumulation of gravels.

DEPOSITS OF HEMATITE.

A noticeable feature of the ore deposits of northern Yuma County is their general association with hematite, which at times is in such quantity as to place them in the category of iron ore deposits. The presence of gold and copper account for the attention which they have received, the iron ore having been frequently considered a "gossan" and the prospectors have concluded that copper sulphides would be formed beneath. These deposits are reported as replacements in the lower strata of Precambric limestone in contact with older gneiss,[1] as irregular veins in "shear zones in the amphibolitic and chloritic rocks;"[1] occupying a sheared zone along the contact of a great instrusive mass with old sedimentary beds[3] and as replacement of quartzite at the contact with older gneiss, the iron ore being derived from alteration of the ferromagnesium minerals in the adjoining rocks.[2]

The observations described in this chapter were made mainly in the vicinity of Brown Mountain, where deposits of hematite occupy shear zones in the basal gneiss and partly replace included dolomite beds. The relationship of Precambric gneiss and included limestones and dolomites, later limestones, deposits of specular hematite, absence of an intrusive and recent volcanism, present a problem not without complexity or interest. North of Brown Mountain, in the vicinity of Planet and along Mineral Wash the geological conditions are somewhat different; the presence of an old rhyolite porphyry and a late one adding other interesting features to the problem.

At Brown Mountain within an area of some two thousand acres, the iron ore outcrops prominently; the deposits measuring from fifteen to two and a half feet in width and dipping at angles varying from 80° to 18° from the horizontal. Associated with the massive and crystalline hematite are ores of copper carbonate and chrysocolla.

The basal gneiss, as previously stated, everywhere bears the results of having been subjected at some time to severe dynamic forces, obliterating its original structure. It is of interest that, at Brown Mountain, were obtained in several instances samples which showed only a moderate amount of shearing and disclosing the facts that the basement originally crystallized under conditions which allowed of the formation of large phenocrysts and a granitoid structure. The majority of the slides, however, show that dynamic forces almost completely destroyed the granitoid texture and developed in its place a granular ore, with a more or less definite alignment of the crushed and broken fragments. Later forces, apparently of less magnitude, operated along lines and zones of weakness previously developed. This action is indicated by the aligned struc-

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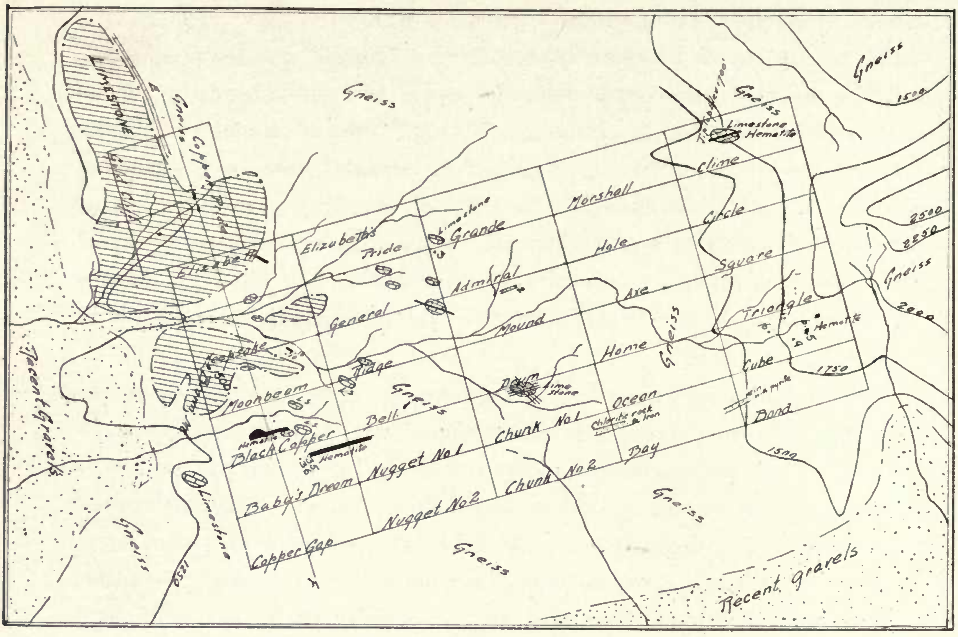
[1] Bancroft, H. p. 40, Bull. U.S.G.S. 451.

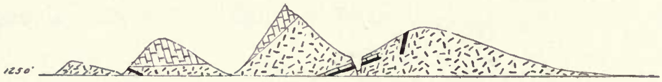
[2] Upham, W. E. Specular Hematite Deposit, Planet, Arizona. Mining and Scientific Press, April 15, 1911.

[3] McCarn, H. L. The Planet Copper Mines. Eng. & Mining Journal, Vol. 78, p. 26, 1904.

Map 3



GEOLOGIC MAP OF BROWN MT. AND VICINITY



SECTION ALONG LINE E F.

The Limestone mass is separated from the Gneiss by a Fault Contact

ture of the introduced minerals, which invaded the gneiss and by the elimination in places of the previous alignment of the original minerals and their resulting accommodation to the forces attending the secondary introduction. Cross fracturing of individual minerals also afford evidence of these forces. The comparative weakness of the dynamic action is best attested by the non-disturbance of the overlying Precambric limestone, beyond a degree, which allowed of a readjustment, eliminating to a great extent any effects caused by these later forces. Also the invading solutions penetrated only a short distance from the greatest zones of disturbance and deposition. The result of mineral introduction and consequent developments added to the gneiss, quartz, chlorite, epidote, sericite, biotite, hornblende, muscovite, calcite and hematite, in amounts depending upon the proximity to the path of the mineralizing solutions. The strike of the gneiss varies greatly, from almost south to north of east. The dip is generally about 40° to the east or southeast.

The Precambric metamorphosed limestone caps Brown Mountain, whose conical shape is distinctive among the other foothills of this portion of the range. The limestone apparently occupies its present position as the result of complicated faulting and at the contact with the gneiss there is evident crumpling and plication of both limestone and gneiss.

There is an absence of breccia. Thin sections of rock at the contact also show evidence of much shearing and crushing, besides developing in the gneiss a granular texture. Near the contact, a block of limestone is separated from the main body and stands between walls of gneiss. It at first sight suggests intrusion of the gneiss, but the weight of evidence favors its having been faulted into the gneiss during the period of shearing. A similar relationship was noted in Planet Wash. This contact at the top of the mountain dips sharply to the northwest and the strike of the limestone is N 70 W with a dip 80° to the southward. In some places in the limestone exposure the dip is less steep. Veins of quartz, calcite and hematite followed the bedding and frequently cut across it. Some beds one foot to two feet in width have not been affected, and are dull gray in color while the mass of the limestone is prevailingly dark brown and is either smooth from the development of desert varnish or rough from differential weathering of the unaltered and altered parts. A thin section (4B) at the contact shows the calcite grains stained almost beyond recognition by brown ferruginous products. Vein quartz makes up most of the section, while hematite grains are present in fair amount. Twenty-five feet above this on the top of the mountain (31) the limestone consists of a closely interlocked aggregate of calcite grains with numerous large grains, much larger than those of the groundmass. Veins occur containing quartz. Hematite grains are scattered in groups throughout the section. Dark brown and yellow iron alteration products are present to such an extent that the rock's color thereby results. No disturbance is noted in the calcite grains, neither the twin lamellæ or boundaries of the grains being affected. A very hard specimen of the limestone (B 25) showed quartz, which had replaced most of the calcite. There was an absence of alignment.

The limestone was originally comparatively pure. The percentage of silica, alumina and iron oxides must have been very low as there is no development of the usual minerals—tremolite, pyroxene, epidote and other silicates of lime or of lime and alumina which form during metamorphism if quartz or kaolin were originally present.

The source of the metamorphism cannot be assigned to the proximity of an intrusive body or its solutions as the absence of any intrusive eliminates that factor. The decipherable history of the rock is practically nil, but it is not impossible that some of the metamorphism can be attributed to recent volcanism, as it is quite likely that the basalts to the west once covered this area as well. All the evidence shows replacement of calcium carbonate by solution from without and to these introductions the limestone owes its present impure state.

Near the contact in the gneiss is a dark rock some 18″ in width; in the field it appears as a dike; under the microscope (39) it resolves itself into a groundmass of fine-grained granular quartz. A few large flakes of chlorite occur and hematite grains are frequent and dark brown alteration products are present in large amounts. The rock shows evidence of severe crushing and is similar in all aspects to the rock on Claim Admiral (2), and is probably a highly metamorphosed sediment included within the gneiss.

Besides the Precambric limestone capping Brown Mountain, there are the uniformly white or pinkish crystalline limestones and dolomites, occurring between walls of gneiss and above or below the veins of hematite. If these limestones have a strike or dip, it is one conforming to that of the enclosing gneiss, but varies widely in this respect. They are considered to be remnants of an Algonkian formation into which the gneiss intruded. Under the microscope the dolomite may consist of large undisturbed grains as in specimen 12, or the grains have been disturbed with introduction of calcite, accompanied by quartz, hematite and needles of amphibole. It is probable that the calcite introduction took place at the same time that calcite entered into the younger limestone. Another prominent feature is the frequent occurrence of an impure calcareous surface deposit described on page 31. It frequently contains large irregular masses of hematite when near a deposit of ore but when it occurs in other places it includes portions of the surrounding rock. It

DOLOMITE (ALGONKIAN)

apparently is the result of hot spring action and is of recent formation. In association with the iron ore deposit near Dale, San Bernardino County, California, in the Colorado Basin, E. C. Harder and I. L. Rich[1] report "surface deposits consisting of small angular fragments of iron intermixed with a few rock fragments and embedded in a compact cream colored matrix of mixed calcareous and siliceous materials, occur at several places near the large veins. Some of these are several feet in thickness and cover considerable areas, overlying either ore veins or country rock. Others fill fissures in iron ore veins. Fragments in these deposits may be several feet in diameter and such fragments may contain open fissures that are refilled with some cementing material. At a few points the deposits contain only rock fragments, iron ore being absent." No genesis is advanced for these deposits, but the description on the whole might be that of the deposits at Brown Mountain.

The origin of the calcareous breccia deposit seems to be more or less definite. The large rounded forms at its base with inclusions of country rock, with at times more or less definite arrangement, and its superposition over the country rock with penetration down into it along bedding planes, together with its siliceous content, development of secondary minerals and micro structural alignment—all are indicative of a deposit formed by the agency of hot spring waters from below. The comparatively fragile nature of these deposits would prohibit them withstanding an erosion, capable of removing hundreds of feet of basalt.

The microscopic slides examined and field observations allow of the following conclusions as regards the ore deposition. The gneiss was originally practically homogeneous throughout this area and is a part of the basement gneiss. It cooled under conditions which allowed the development of a granitoid structure, which was subsequently generally fractured by dynamic forces without any particular alteration taking place in the rock mass. Later it underwent regional dynamo-metamorphism, aligning the original minerals, with the introduction of quartz in quantity, materially modifying both the texture and mineralogical composition of the rock. Zones of weakness due to complex shearing were developed in various directions, frequently intersecting. Silicification was especially developed in these zones of severest crushing. At a later period in the rocks history and presumably after the alteration of the plagioclases had set in, the secondary minerals—epidote, chlorite, biotite, amphibole, muscovite and calcite—were developed, probably simultaneously with the entrance of the mineralizing waters or vapors which carried the iron and lime which either formed in veins in the gneiss or replaced gneiss, Precambric limestone or earlier limestone and dolomites. Excepting the primary silicification, followed by shearing, the other phases of the introduction seem to have fluctuated, with silica introduction appearing in the latest formed calcite veins. Movement throughout the weak zones seems to have been more or less continuous and may have continued up until quite recently as shown by blocks of gneiss with slickensides of hematite. Epidotization has not penetrated far from the zones of crushing or deposits of hematite.

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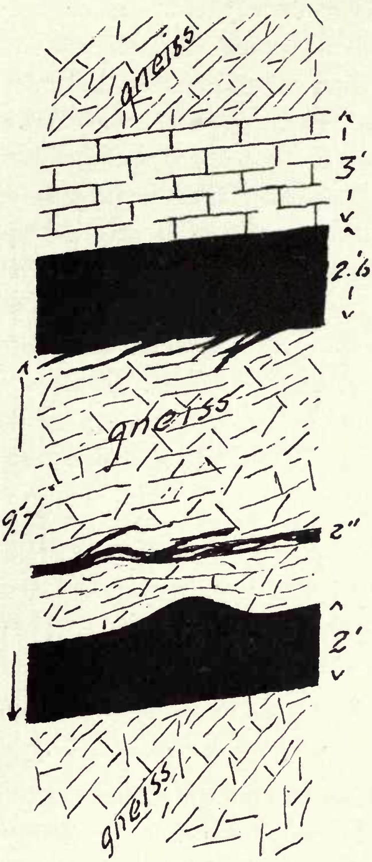
[1] Bull. U.S.G.S. 430, pt. 1, p. 238.

HOT SPRING DEPOSIT

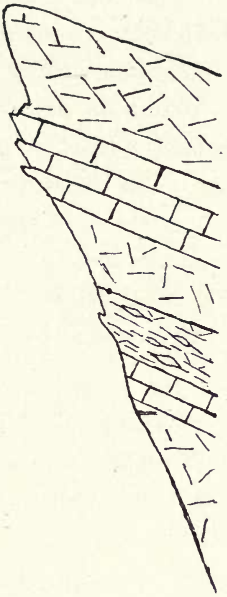
The largest veins are to be found in shear zones and replacing strata of included dolomites, and as veins in the gneiss. There is no consequential deposition in the Precambric limestone, which appears not to have been greatly affected and generally free from veins of iron ore. When it does occur it is along bedding planes.

Secondary Minerals.

QUARTZ: There is little or no evidence of this mineral having been formed by action of carbonated waters on plagioclase feldspars with the development of the "albite mosaic" and the formation of calcite, the latter forming epidote and zoisite, except in the gneiss near deposits of hematite. Throughout the gneiss mass as a whole it seems to have been largely an introduced mineral.



IRON ORE ON BLACK COPPER



Limestone on Claim
Copper Ridge.
Looking East.

CHLORITE: The formation of this mineral from the original ferro-magnesium minerals is noticed only to a limited extent, but undoubtedly its presence represents their former existence. Its prominent development, however, seems rather to be due to a condition set up by altering feldspars and mineralizing solutions carrying iron compounds. If the former origin is to be assigned to the chlorites it is not clear why the chloritization should have been so universally complete and that there are so few remnants of the parent to be seen undergoing the breaking down process necessary for the chlorite's development. That it has been formed simultaneously with epidote is frequently evident and at times it appears to have been derived from the latter.

The association of hematite and chlorite in the gneiss away from the ore bodies is not readily explained, unless it is taken that the iron hydours compounds have resulted from decomposition of chlorite, with subsequent change to crystallized hematite. Its universal occurrence however in the crushed zones lead rather to the conclusion that hematite was precipitated and chlorite formed by conditions set up in the rock, due to solutions from without.

EPIDOTE: Its presence only in the gneiss adjacent to an ore body indicates its derivation from pneumatolytic action. Epidote does not seem in any case to have been derived from chlorite or from the interaction of altering plagioclase and original ferromagnesium compounds.

HORNBLENDE: Hornblende is practically confined to the crushed zones in the immediate vicinity of ore deposition. Its formation is dependent upon conditions existing in these zones, and it does not appear to have been formed from any one particular original mineral. Its long slender needle like form suggests crystallization under conditions of falling tempertature. Larger crystals show alteration to biotite, which always appears to have had a history similar to that of hornblende.

SERICITE AND MUSCOVITE: These appear to be among the first alteration products, and show derivation from both plagioclase and orthoclase.

CALCITE: This mineral has undoubtedly formed from alteration of plagioclase in contact with carbonated waters, but has probably been taken up in the formation of epidote, as it does not seem prevalent, except where it fills veins.

DOLOMITE: Dolomitization was effected before the period of mineralization.

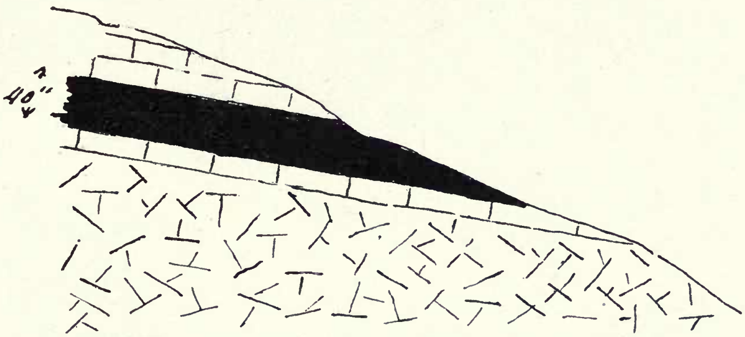
HEMATITE: In the majority of cases this mineral appears to have been an introduction from without, although as stated under chlorite, some of it may have resulted from that mineral having broken down to limonite, which later developed into hematite.

PYRITE: When pyrite occurs it has formed earlier than hematite but later than some stages of the silicification. Its derivation as the result of propylitization, which its environment seems to favor, is the only satisfactory explanation for its occurrence.

IRON HYDROUS COMPOUNDS: The omnipresence of these compounds in the rock adjacent to zones of crushing show their origin as dependent upon conditions which developed after general metamorphism. They represent the final adjustment of the iron compounds introduced from without and set free by general alteration and dissociation of the mineral content of the gneiss.

COPPER: The carbonates of copper are essentially secondary minerals and appear to have formed by the action of carbonated waters upon some copper compound whose identity is not disclosed. It was probably present in the mineralizing solution as copper does not form away from the heavily mineralized zone as does hematite. This seems to exclude its having been an original constituent in the gneiss. The silicate of copper, chrysocolla, is found similarly to the carbonate and its formation is probably due to the action of silicious waters on some soluble copper compound. It retains its peculiar concoidal form even in the thin section, and the formation is indicative of water solutions and not of vapor.

In the little crushed portions of the gneiss and in the outer zones of severe crushing, the sequence of secondary mineral development seems to be first, introduction of secondary quartz, with development of sericite, followed by chlorite and hematite. In zones of greater crushing and alteration by mineralizing solutions, the above condition seems to be followed by the appearance of a later invasion of quartz and the development of epidote, chlorite, calcite, hematite, amphibole, biotite, and lastly quartz, calcite, and iron hydrous compounds. The last however may appear at any stage. In fact, a composite sequence is not truly representative of the actual conditions, which rather appear as overlapping of several stages of mineral development. The most consistent sequence is the first introduction of quartz previous to crushing which was followed by the fluctuating development of the majority of the secondary minerals. Another definite stage is the appearance of hematite later than the formation of the crystalline limestones and dolomites, and that calcite with quartz seems to have been the finishing stage. Copper as carbonates and silicates is later than hematite and earlier than the last calcite-silica introduction or rearrangement. Migration of secondary minerals has evidently taken place to a large extent and obscures the chronological order of the metasomatism and mineralization.



IRON ORE IN LIMESTONE CLAIM GENERAL. LOOKING NORTH.

South of the Williams River is an area of considerable iron and gold mineralization.

The geology is somewhat different than that at Brown Mountain, as the gneiss has been intruded by an old rhyolite porphyry; and since the deposition of detrital beds a more recent rhyolite porphyry has been intruded into the complex. Quartz veins of some magnitude and well mineralized cut through the older porphyry. Limestone and other sedimentary beds rest unconformably upon the eroded basement and the basal members of the limestones are reported replaced by iron ores at Planet, where amphibolite is also reported intercalated with the lower limestone beds.[1] No report seems to have covered completely the geologic relationships which exist in this limited area and this report is

QUATERNARY RHYOLITE PORPHYRY MINERAL WASH equally incomplete. The writer observed rhyolite porphyry in contact with the basal gneiss, along the south wall of the Williams River, near Mineral Wash. It forms the cores of most of the rugged foothills which extend south towards Planet Peak. In the field it is quite similar to the gneiss. On its previous rugged topography, the Temple Bar conglomerate was layed down and erosion has not completely removed these beds from the former gulches. Cutting through the detrital beds and also in contact with the older porphyry is a younger rhyolite porphyry, which is the prominent and distinctive red rock, which caps the rhyolite porphyry foothills.

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[1] Bancroft, H. Bull. U.S.G.S. 451.

The detrital beds are metamorphosed and stained red near the contact with the intrusive, their original color gray, still being retained by the beds away from the contact. Rhyolite porphyry, on the south side of Mineral Wash, has been greatly altered to sericite and mica schist near the contact with the younger intrusive. The soft material in the joint planes of this rock carry gold values as high as $4.00. The older porphyry is cut across by large veins of quartz, carrying gold readily distinguishable by the eye, the vein matter consisting entirely of quartz and large amounts of iron compounds. Veins containing chrysocolla, copper carbonates and hematite also cut the older porphyry. Veinlets of hematite and quartz ramify through the younger rhyolite porphyry, which has also been invaded by the solutions carrying gold. At the contact of the two porphyries mineralization of some description has usually taken place. Veinlets of jasper, characteristically occurring in the basalt, cut both porphyries. Both the older and younger intrusives show similar mineralogical character, except that a sample of the younger porphyry, taken along the south wall of the river about a mile west of Planet showed the introduction of vein quartz. A prominent ridge of rock, having the same outward red color and general appearance was noted at the mouth of Planet Wash, directly overlying the gneiss. It was considerably more oxidized and cut by minute veins of hematite. At the contact considerable mineralization has taken place, with development of iron ore and copper carbonates and chrysocolla. On examination, however, a thin section displayed nothing but an aggregate of vein quartz and some granular grains of quartz similar to those of a quartzite. It contains quantities of iron hydrous compounds and large hematite grains. Considered by itself it would probably be called a quartzite and has been heretofore so interpreted. Its position in the field and characteristic coloring, which is associated with only the younger rhyolite porphyry and beds in immediate contact, has raised the question of its being a silicified phase of the rhyolite porphyry. Silification has been such a constant association with the ore developments, that this view cannot be readily dismissed.

Bancroft and Upham have described the geology of the Planet mine in detail. Some observations, however, were made, which are pertinent to the ore deposition at Brown Mountain.

South of Sentinel Hill, which is composed of limestone, the gulch cuts through to the gneiss and some way up the north side of the gulch, a portion of the limestone was observed, separated from the main mass of limestone by gneiss. A veinlet of hematite crossed through the gneiss and the separated portions of limestone, bifurcating in the upper beds. Microscopic examination of the limestone gave these results. (14B) It is a mass of calcite, the individual grains being mostly consolidated together, eliminating boundary lines. The calcite mass is crossed by veins filled with quartz, epidote, chlorite and hematite and crystals of calcite. There is a network of these veins. A large amount of iron hydrous compounds are also in the veins and a few large opaque masses, deep red in color, appear to be altered hematite. Epidote is reddish in color and shows marked pleochroism. Some dolomite grains were present. The detached lower portion (15B) consisted of a mass of individual calcite grains. One or two veins cross the section, filled with calcite, chlorite, hematite, and brown iron products. Little or no quartz was observed. Some epidote was seen but in much smaller amount than in the above section. The detached portion seems to have been much less affected by the mineralizing solutions, although in close proximity. Neither section varied from sections obtained at Brown Mountain, and the direct contact with gneiss and detachment of a portion of the limestone is likewise similar.

Besides the ores usually mentioned as occurring at the Planet, brochantite was noted[1]; it also occurs at Mineral Hill.

The main deposition is considered to have taken place along the contact of the limestone and underlying gneiss, with replacement of both.

Several miles southeast of Planet, near Planet Peak, there appears to have been a centre of volcanic action, the basal beds of the Temple Bar are changed to a resistant red sandstone and highly tilted. The limestone is also tilted to the southward and much deformed.

ORIGIN OF THE ORES IN THE VICINITY OF WILLIAMS RIVER.

The locality has evidently been one of volcanism at different periods, ranging from the Precambric to recent times. The facts on this point are consistent and conclusive. At what period the ores came in, or if they are the result of a combination of all periods is an interesting question. That gold is associated with the latest intrusive is more or less definite and that the intrusive is also higher in its iron content, seems clear; the earlier porphyry and gneiss, being notably low in original ferromagnesium minerals and in introduced hematite and iron hydrous compounds. Silicification is characteristic of the mineralizing solutions. Jasper is known to occur as prominent veins in the basalt. All the different rocks have apparently been subjected to the same degree of oxidation, since denudation has taken place, yet despite that there is no great difference in their compactness, the younger intrusives and beds in immediate association are the most conspicuously red colored rocks in the region. The other rocks, excepting the limestone, with its desert varnish, are prevailingly gray. Calcite is an abundant gangue mineral and occurs in veins in all the rocks in the vicinity of ore deposits. Precambric ore deposits are not as common as those of later periods, and it is not satisfactory to assign ores of this type to the Precambric in the absence of overlying known Cambric strata, which have not been affected by mineralization. In this region the latest intrusives are mineralized. The above evidence seems to favor a later occurrence than that of the Precambric, although strata of that age have been more favorable for ore deposition.

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[1] Determined by E. L. Bruce, Mineralogical Dept., Columbia University.

At Brown Mountain the geologic conditions vary from the above, owing to the absence of any recognized intrusive whatsoever. That recent volcanism has taken place is evident from the recent craters and the tilting of a great mass of the Temple Bar conglomerate. Jasper, with a high percentage of hematite, occur as large veins in the recent basalts, which have also a high iron content. Hematite or other iron ores are practically absent in the gneiss except along shear zones.

It is evident that ore deposition was not a consequent of the intrusion of the basal gneiss, as the veins penetrate limestone, laid down after its consolidation and presumably also after a period of erosion. The evidence is not conclusive for late deposition, yet as there is practically no evidence for the less common deposition in Precambric times, the mineralization is considered as probably belonging to a later period. Bancroft[1] notes as definite, one period of mineralization as Tertiary, in northern Yuma County and considers the some deposits of near Swansea as probably of this age. This would appear to be in keeping with the known periods of mineralization throughout the basin region.

[1] Bull. 451, U.S.G.S., p. 36.

The exact nature of the origin of specular hematite in nature is not fully known. The specular hematites in this locality are well developed, but their genesis is not so evident. It can hardly be assigned to arid conditions as the mineral seems to have crystallized directly from solution, with long, slender needles, penetrating into the surrounding rock structure, and having a well defined radial structure. There is no conclusive evidence of its having formed from some other oxide, as magnetite, and in the absence of such evidence, also considering its general character, the supposition of its having crystallized directly, from hot magmatic solutions, seems to conform more with the observed facts. That is has replaced limestone and dolomite in so doing is generally attested. The facts seem to allow only of the deduction that the iron was precipitated from a ferric solution either in the limestone and dolomite strata or by the calcareous solutions which apparently penetrated the gneiss and limestones, previously and simultaneously with the entrance of the iron bearing solutions. Such an explanation would require that the solutions were hot and magmatic in their source. The sequence of silicious, calcareous, ore bearing, calcareous-silicious, solutions has been determined, but the exact nature of the deposition can only be assumed.

SPECULAR HEMATITE

At Brown Mountain, in the absence of any intrusive, to which the accompaniment of magmatic waters could be assigned, they have been attributed to the volcanism which has been so prominent in the immediate locality. These solutions penetrating through a mass of rock, in which previous shear zones were probably re-opened and new ones developed, by the crustal disturbances, found favorable conditions for deposition of their mineral content, in the dolomite strata or in the gneiss itself, owing to conditions established between the solutions and the mineral components of the gneiss.

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APPENDIX.

The description of many thin sections examined are placed in this appendix.

18. Gneiss on Moonbeam, near deposit of Hematite.

This section is a fine aggregate of secondary minerals. The groundmass consists of secondary quartz in mosaic patterns and of minute fragments of feldspars. No phenocrysts are present, except for a large single badly altered plagioclase. The groundmass shows pronounced alignment. Epidote is present in large amounts. Its color is bright yellowish green, with marked pleochroism. Extinction is parallel to the cleavage in section parallel to "b" axis. Clinopinacoid sections occur. The epidote occurs as large aggregates, always associated with chlorite which is present in almost equal amounts and at times surrounds epidote. The chlorite also occurs by itself and in veins in the groundmass and also cutting the structural lines, showing some of it to be later than the crushing of the rock. Other large aggregates of chlorite are to be seen swimming in the structure lines. Berlin blue and dark brown interference colors prevail. Titanite crystals are frequent and often altered. Some apatite crystals are surrounded by chlorite. Long stringers and masses of hematite occur, following along veins of chlorite, in disconnected crystals. It frequently cuts across chlorite flakes, and at times includes quartz and portions of the groundmass. Hematite is also found around pseudomorphs of chlorite after feldspars. It appears also to have migrated.

This rock, no doubt, represents what took place in the outer limits of the zone wherein the iron ore was deposited in large amounts. The presence of epidote and chlorite are to be noted. A sample (13) of gneiss impregnated with ore, gave these results.

The groundmass is a fine grained mosaic of secondary quartz, arranged in flow lines. Some larger crystals of quartz occur. No feldspar fragments are to be seen. Light green chlorite with dark brown interference colors occur in large masses and arranged in broad bands in general direction of flowage. Epidote is present in large amounts, as granular aggregates and also as tabular crystals, elongated parallel to ortho axis "b." It is greenish yellow in color and shows pleochroism. It has high interference colors. The extinction is parallel to cleavage in sections parallel to the "b" axis. The cleavage is frequently definite. Granular aggregates are arranged in the same direction as the flow lines of the groundmass and in veins across it. Quartz grains conform to crystal boundaries of the epidote frequently. Alteration at times is noted. Apatite in small crystals and basal sections are numerous. Hematite occurs in large masses with narrow long needles protruding into the surrounding groundmass and chlorites. It has inclusions of quartz, chlorite and epidote. It also occurs in elongated shapes conforming to weak lines in the section, such as cracks across the groundmass. It does not appear except associated with chlorite and epidote. The hematite is clearly shown to be the latest of the minerals to be introduced.

10. Gneiss above ore, Moonbeam shaft No. 2.

Large phenocrysts with groundmass of fragmental feldspars, secondary quartz and sericite. The groundmass is arranged in shear lines and around and between phenocrysts. Large crystals of microcline, without crystal boundaries occur. Plagioclase is next in amount and some orthoclase. Crystals are fractured and torn. Plagioclase is frequently fractured at right angles to bandings and also shows wavy extinction and other evidence of severe strain. The plagioclase proved to be albite. Sericite forms large portions of the groundmass and epidote and calcite also are to be seen in it. The titanite is usually in groups.

Chlorite with Berlin blue interference color occurs as flakes and as veinlets throughout the section. Remnants of green colored biotite are present.

Large irregular masses of hematite are surrounded by red alteration products. A large mass of the same alteration products with definite boundaries exist within an irregular mass of hematite which has also feldspar inclusion. On claim Black Copper, the hematite dips at 18° in a northerly direction, which should carry it under Brown Mountain. At one place along the strike of the vein the outlying gneiss has been removed by erosion, exposing a considerable area of massive iron ore. An incline follows the ore down one hundred feet and then passes beneath the ore. Northwest of the incline across a small gulch, a shaft (Shaft No. 2) was sunk and encountered the ore at a depth of 50 feet, from where it was again followed. Not far down on the incline, a series of samples were taken of the foot wall beginning nine feet beneath the ore.

40. Foot-wall 9 feet below ore.

Rock is composed of broken fragments of orthoclase, microcline and plagioclase, scattered through a groundmass of secondary quartz, which has invaded the rock in wide zones. The fragments of feldspars are fresh, and most of them are badly shattered, while others retain their crystal boundaries. Many of them are drawn out, conforming to the alignment of the invading quartz. Within the groundmass are numerous grains of epidote, shreds of amphibole and muscovite, and flaky chlorite. The epidote occurs partly crystalline or as tabular masses. Its color is almost white and its pleochroism faint. Interference colors are high. Several acute rhombic sections occur. The grains or masses are scattered throughout the groundmass or arranged in stringing line.

Amphibole, chlorite and muscovite accompany epidote in the crushed portion of the rock. Severe crushing has evidently taken place. No iron ores to be seen.

45. Foot-wall 8 feet below the ore.

The minerals are principally arranged in structure lines. The crushed portions of the section consist of small quartz grains and feldspar fragments, which are principally albite and microcline. They are usually fresh but much shattered. Some of the plagioclases show slight alteration. Chlorite with dark brown interference colors is present in large patches and also in veins, which cross the major structure lines. Some muscovite shreds and epidote grains are associated with masses of hematite, elongated in direction of structure and connected with other masses by small grains; it also shows migration.

42. Foot-wall 6 feet below ore.

The character of the rock changes little, the larger fragments of feldspars are badly strained and fractured and the intervening spaces are filled with smaller fragments and secondary quartz. Shreds of biotite and yellowish green epidote grains ramify in long stringers between the crushed crystals. Hematite is present in detached groups with chlorite associated. The lines of crushing are distinct.

43. Foot-wall 4 feet below ore.

Large fragments of microcline, orthoclase and plagioclase, fresh but badly crushed, are surrounded by a groundmass of similar finer fragments; fresh epidote and biotite are aligned and surround plagioclase fragments. Hematite is present as large irregular masses and as stringers, arranged along structure lines. Hydrous iron compounds fill every crack and fissure throughout the section. Some of the hematite is completely altered to these red products.

48. Foot-wall 2 feet below the ore.

The principal part of the section is a mosaic of secondary quartz with fragments of plagioclase. One portion of the section consists of large crystals of plagioclase, fractured, and corroded by secondary quartz and replaced by chlorite and the crystals are allotriomorphic. Large amounts of chlorite showing Berlin blue interference colors, occur with considerable yellowish green epidote, both in the same alignment as the groundmass. It fills fractures in plagioclase, and is crossed by veins of secondary quartz.

Dendrites of hematite penetrate fractures in plagioclase, crosses masses of chlorite and are arranged along direction of the groundmass. The hematite is always crystalline with protruding needles. It is often surrounded by epidote. The groundmass shows distinct shearing in wide zones. Several plagioclase fragments were determined as albite. Epidote is intergrown with other members of the group. Hornblende is present only as minute slender needles.

41. Foot-wall just below contact of iron ore with foot-wall.

The rock is a groundmass of secondary quartz, very fine grained, arranged in structure lines. A few phenocrysts of quartz occur. In ordinary light the rock appears green, owing to the large amount of chlorite present. This occurs in large masses, in veins across the flow lines and also arranged in lines conforming to the direction of flowage. Large masses of iron hydrous alteration products occur, similar to the alteration products of hematite. The chlorite shows Berlin blue interference colors. Aggregates of granular epidotes showing marked pleochroism and greenish yellow in color, occur. Several portions of the flakes show parallel cleavage.

Further down the incline a sample 2 feet below the ore gave these results. (49) Rock composed of small sheared angular grains of orthoclase, microcline and plagioclase in a dense greenish groundmass, which in places resolves into sericite, quartz, chlorite and epidote. Greenish hornblende with pleochroism and small extinction angles occur in xenomorphic crystals of some size, altering to chlorite. Veins filled with quartz, epidote, hornblende, and chlorite cross the groundmass, the minerals arranged with long axes across the vein. Small greenish slender needles of amphibole occur in clusters and penetrating into the other rock fragments. They are especially noticeable when they penetrate feldspars, and are most abundant in the veins. They are evidently secondary. The rock seems to have been compressed after shearing. No iron products were noticed.

At the contact of the foot-wall with the iron ore the (44) section is a mass of crystalline hematite with its needles protruding into completely surrounded masses of chlorite. Veins in the hematite are filled with dark brown alteration products.

A sample (46) of vein matter 30 feet from the collar of the shaft was found to consist of large grains of dolomite, showing cleavage and polysynthetic twinning. A groundmass of smaller grained calcite has eroded and effaced a high percentage of the large dolomite grain. The twinning is not disturbed. Some secondary quartz has been introduced, together with crystals of hematite, in veins of calcite crossing the groundmass.

29. The vein matter at the bottom of the incline was composed of large crystalline dolomite grains, which have been broken and the inter-

vening spaces filled with the calcite groundmass. Veins filled with calcite and small strings of hemitite cross the section. At the bottom of the incline, when it passes beneath the vein, the gneiss is encountered. It is probably some fifteen or twenty-five feet beneath the ore. It gave the following results:

30. The structure is granitoid. All the principal minerals have been torn, crushed and distorted. Few crystal boundaries remain, and the section appears to have been subjected to heavy shearing forces. The principal minerals are orthoclase, microcline and plagioclase, all readily distinguishable. The plagioclase allows a test which shows it to be albite. Orthoclase retains its crystal boundary at times and the crystal shows parallel cleavage and cleavages intersecting at 90°. Carlsbad twinning occurs parallel to the edges of the crystals. Orthoclase and microcline are unaltered, while the plagioclase is. Inclusions of apatite occur in many of the feldspar crystals. Titanite crystals of fair size also occur between the feldspar crystals. Biotite occurs in small flakes, badly altered to chlorite, but still retains cleavage lines and its pleochroism with strong absorption parallel to the cleavage lines. Its color is light brown. Chlorite aggregates usually, have biotite for a centre. Chlorite fills fractures in the feldspar. In this section its interference colors are normal. Hematite is quite in evidence. It is usually associated with chlorite, but occurs occasionally as inclusions in plagioclase. Generally, crystallization has taken place to such an extent that some of the crystal boundaries have been formed. The crystals show no alteration. The minerals have a marked alignment and in places large feldspar crystals are surrounded by flow lines of crushed material. Broken crystals of various sizes, chlorite and secondary quartz of mosaic patterns fill the places between the large crystals. This material has penetrated into the less disturbed portion of the section, corroding and filling fractures of the feldspar. These veins form a network through the section and are often filled with dark yellow secondary products with hematite associated. A favorite habitat of the hematite seems to be where chlorite is in conjunction with feldspars. Several hexagonal sections occur. They remain dark under crossed nicols during complete rotation, being basal sections of apatite. Epidote is also frequent, both as large and small crystal. It is colorless showing very slight pleochroism.

37. Sheared rock in vein below the hanging wall, 100 feet down on the vein. The rock is badly decomposed. Epidote is the chief crystalline mineral, occurring in large well-preserved crystals. It is colorless with well-defined cleavage. Crystals are short and prismatic. There is no particular alignment of phenocrysts. The groundmass, however,

swings around the phenocrysts and across the section, and is composed of sericite and chlorite. It is not granular in appearance, but fibrous and fills fractures in the epidote. Some quartz grains are present and are at times included in epidote. Alteration to a degree of cloudiness has taken place in many of the epidotes. Chlorite is abundant and forms around large crystals of epidote and occurs in flow lines. Light green hornblende and shreds of brown biotite occur.

47. The iron ore in the veins proved to be a mass of hematite, crossed by a network of veins, some extending into the iron until they become minute fissures. When small, the veins are filled with hydrous iron compounds, but on expanding, with calcite. The large veins have attacked the hematite, and vein matter surrounds masses of hematite. Copper as a green carbonate and chrysocolla occurs in these veins and seems to be later than the calcite vein matter.

Hanging Wall Shaft No. 2. This rock is similar to 49. Granular fragments of orthoclase and plagioclase are in an opaque greenish groundmass of micro quartz and sericite. The plagioclases are altered to sericite, which at times encloses chlorite. Epidote is present as colorless grains in the groundmass. Greenish secondary hornblende is frequent either as xenomorphic crystals or minute slender needles. Secondary quartz is more abundant than in 49, but hornblende somewhat less so. A few grains of hematite are to be seen. Shear structure, invasion of secondary quartz, with its corrosive action on feldspars are the noticeable features.

33. Hanging Wall at bottom of incline.

The rock is an aggregate of yellowish green epidote. Some large masses show cloudy alteration. A vein filled with epidote crosses the groundmass. Hematite occurs in large irregular masses. The hematite near its outcrop on the surface is overlain by six feet three inches of white dolomite conforming in dip with that of the hematite.

34. The dolomite consists entirely of large closely interlocked dolomite grains, which show well-defined rhombohedral cleavage; also polysynthetic twinning and are often bowed and out of alignment by cross fracturing. Crossed twin lamellæ are also well-developed. Where grains are fractured bent and otherwise shattered, intervening spaces are filled by a fine groundmass of calcite, with definite alignment. A small amount of light brown alteration products and also a few minute grains of hematite occur in cross veins. This dolomite outcrops between walls of gneiss in other places on the claim and varies from almost a pure limestone to a dolomite. Where erosion has removed the overlying

gneiss it covers the area with white, small blocky masses, indicating its former presence.

The consistent presence of the fresh characteristic feldspars of the gneiss, the evident shearing that has taken place, the absence of otherwise than secondary ferro-magnesium minerals, and total absence of any minerals which are not well-developed in the gneiss, favors the conclusion that the ore has occupied a shear zone in the gneiss, as it does in other instances and is not the replacement of any basic intrusive or associated with one.

Claim Baby s Dream:

On the adjoining claim, Baby's Dream, to the south, farther away from Brown Mountain, is an outcrop of rock, highly impregnated with iron ore, alongside of which is a vein of hematite dipping slightly from the vertical, to the north.

35. This outcrop shows a groundmass of secondary quartz, arranged in shear lines and at times surrounding an occasional, distorted feldspar crystal. Fine grained calcite forms a considerable part of the groundmass, but fine grained secondary quartz predominates, seeming to be an earlier introduction. Hematite as large radially crystalline masses, encloses epidote, chlorite and areas of secondary quartz and from its mass long needles penetrate into the groundmass. Chlorite and biotite are present as shreds and amphibole as minute needles. The first two and epidote are enclosed by calcite. Biotite is often altering to chlorite.

A sample of gneiss, from part of the foot-wall showed fragments of orthoclase and plagioclase in a fine grained groundmass. In ordinary light the groundmass has a decided alignment and likewise have the feldspar fragments, which appear to have been sheared into alignment. Minute fragments of the feldspars, quartz and chlorite form the groundmass, which has been invaded by zones of secondary quartz, also showing the effects of stresses.

The cropping on Baby's Dream continues eastward, across claim, Nugget No. 1, on which is also a large mass of white limestone, associated with boulders of hematite. On the adjoining claim, Chunk No. 1, almost in a direct line with the outcrop is a broken area, apparently caused by the crossing of two zones of shearing. The gneiss is here coated with dark purple hematite, which is also present as solid iron ore, with a width of over two feet. Just to the south of claim Chunk No. 2, an area of gneiss is stained green in color with hematite present in veins, twenty to thirty inches in width. The green color is due, no doubt, to chlorite, which is found to be always abundantly associated with hematite.

Claim Copper Ridge:

Two parallel outcrops of limestone, between walls of gneiss outcrop for 75 feet and are capped, as the ground rises, by a ledge of quartz stained green by chlorite and heavily charged with hematite. The gneiss strikes about east and west and dips 80° to the north. A vein of hematite accompanies the quartz ledge. In vertical section, it should be added, the limestone, in one place, turns at right angles to its strike towards the south.

Claim General:

On this claim a vein of iron ore 40 inches in width, lies within an outcrop of limestone, which rests on sheared gneiss. The vein dips gently to the east.

Claim Mound:

Iron ore is here exposed, 40 inches in thickness, overlain by limestone, which in turn is overlain by crushed gneiss. In taking out the ore, the limestone has come out in large rounded blocks.

Claim Admiral:

The hematite outcropping exposes no new features, but a sample of the gneiss was taken near the shaft to determine its character; the claim being about 2 miles distant from the Moonbeam Claim.

(3) The structure is granitoid, with the microcline and albite crystals showing crushing and the intervening spaces filled with secondary quartz which has invaded the section in wide bands, however without any pronounced alignment being developed. Microcline is fresh with crystal boundaries, but the albite has been altered, and its twinning planes displaced by cross fractures. A few orthoclase crystals are penetrated by veins of quartz and also include original quartz. Large crystals of quartz show saw tooth boundaries, closely interlocked, and have been elongated and strained. Crushed fragments of the original mineral fill intervening spaces between crystals. Sericite, shreds of muscovite and biotite appear in crushed zones. There is no chlorite or epidote. Hematite is isolated as irregular small masses and is sometimes altered to red products. Its usual habitat in zones of severe crushing is maintained. It is also peppered throughout the rock. Titanite is sparse.

(2) A dark zone of rock, with the appearance of a dike occurs on this claim. It proved to be similar to the crushed zone near the contact of limestone and gneiss on Brown Mountain.

Claim Square:

The highest point on this claim is about 150 feet above the top of Brown Mountain and forms a sharp dividing ridge, between two gulches. On this dividing ridge, outcrops, between walls of white pegmatitic gneiss, hematite and limestone, with some five feet of crushed material, which has developed into a white, micaceous, calcareous schist. The Cube Claim is to the south at a somewhat lower elevation, on a similar ridge. On the steep eastern side of this ridge occur two vertical outcrops of hematite, between walls of gneiss. The ore measures some twelve to fifteen feet across and presents a face of hematite, highly crystalline, with a brilliant blue metallic lustre. Thin knife-edge crystals, with faces highly polished project from the entire face exposed. There is no apparent alteration. Samples were taken of both the walls and at a considerable distance above the outcrop, on top of the ridge, and also in the face of an 80′ tunnel, driven through the western slope of the ridge, to cut the ore at a level about 200 feet below its outcrop. In this instance, the relationship of gneiss to the ore is not obscured by any other elements, or peculiar phases developed in the gneiss. The iron ore stands simply as a vein between walls of gneiss.

6. Hanging Wall Copper Cube Open Cut.

The structure is granitoid and the crystals are of large size. The rock is fresh and shows signs of having been markedly affected by dynamic forces.

Orthoclase is the predominating mineral, crystal sections being of large dimensions and their boundaries are frequently to be seen. The twinning after the Carlsbad manner is rare. Cleavage lines are distinctly visible. Crystals are badly fractured and show slight alterations along cleavage lines. Apatite is present as inclusions. Plagioclase is next in importance of the feldspars, but is not so large as the orthoclase crystals. It is usually slightly altered over the face of the crystal, and frequently shows wavy extinction. Inclusions of quartz and apatite occur. Owing to crushing, the crystals are badly shattered and few crystal boundaries remain. At times the large crystals show cross twinnings and also in other cases are bowed into an arch. Microcline is sparsely scattered throughout the section. There are the remains of a few large crystals badly corroded by quartz, which occurs in large interlocked aggregates, the grains being of considerable size. It fills spaces between the crushed feldspars, forms veins across the rock and occurs also in mosaic aggregates, forming flow lines around large feldspar crystals, which it has also attacked by corrosion. It appear to be entirely secondary. Basal sections of apatite are frequent. Large aggregates of chlorite permeate the section in all the weak zones, and follow the quartz in its permeation of the original rock minerals. The center of the mass is frequently biotite, which shows marked pleochroism in the direction of its cleavage. This mineral without alteration appears only to inhabit the weak zones, and its form accommodates itself largely to the nature of the crevices, usually being fibrous and much elongated and is without crystal form. There is more biotite than in any other slide. A little epidote occurs in veins. Hematite is frequent as irregular masses, and is connected together by small stringers. It occurs only along fracture lines and in portions of the altered rock.

5. Foot Wall of Copper Cube—Open Cut. Structure is granitoid. Albite is the principal mineral and occurs as large crystals with their boundaries often well-defined. As a rule, adjoining crystals have been crushed together and resulting boundary lines are jagged. Alteration to sericite is almost general, especially along twinning planes. The banding is narrow and frequently bowed and out of alignment by cross fractures. They are frequently corroded by secondary quartz. There are no fresh albite crystals. Large flakes of chlorite which also form around crystal boundaries, are pale green in color, with Berlin blue interference color. It is associated with hematite, which occurs in large irregular masses. Dark brown alteration products occur in fair amount. Apatite is frequent. Considerable amount of colorless epidote is associated with hematite in crushed zones. Interlocking crystals of secondary quartz corrode feldspar. There is no alignment of minerals.

9. Top of mountain by Open Cut—Copper Cube.

Rock is a mass of sheared microcline, plagioclase and orthoclase, and the movement has been so severe as to generally obliterate the crystal boundaries. All the minerals are fresh, excepting those of plagioclase, which shows alterations to sericite. Orthoclase has distinct cleavage. Minute crushed feldspar fragments make up the groundmass and are aligned. Some secondary quartz is arranged along with the groundmass. Chlorite is present in stringers along lines of flowage, with Berlin blue interference colors. Epidote is colorless to brownish and occurs as aggregates in badly crushed portions of the rock. The apatite crystals are long and slender. Remains of biotite also occur in badly crushed portions of the section, as does muscovite shreds—both associated with epidote. Hematite is arranged in long masses stringing out in the

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direction of alignment and usually only in the badly crushed portion of the rock. Chlorite and epidote are in association. Hydrous iron compounds are alterations from hematite, but are not large in amount. When hematite occurs surrounded by feldspar and not in badly crushed zones, it is crystalline. Sericite is in masses conforming to alignment.

16. Eighty foot tunnel Copper Cube.

Rock is composed of large crushed and distorted crystals of microcline, orthoclase and plagioclase. Secondary quartz has invaded the rock in wide bands, showing alignment. The smaller fragments being aligned along with the quartz. A vein contains considerable colorless epidote, which is at times surrounded by secondary quartz. Hematite occurs in large masses, forming around plagioclase fragments, but is corroded by secondary quartz. It occurs in crushed zones in association with colorless epidote, surrounding it at times. Chlorite is present in fair amount.

Over 4 miles to the north of Brown Mountain, a dike associated with gneiss, impregnated with hematite was sampled, as well as the rock itself.

11. Dike Rock on Copper Zone.

Groundness is dark brown in plane light and dark under crossed nicols, except for a high amount of micro-quartz, grains, intermixed with the dark portion of the groundmass. By reflected light the dark portion appears to be made up of minute pieces of hematite closely intermeshed.

Phenocrysts are numerous and appear to be of quartz, pseudomorphic—after feldspar. The outline of several basal feldspar sections are still present and there are numerous lath-shaped crystals. The feldspars have been replaced by quartz, retaining the original crystal boundaries. The grains of quartz within these boundaries have allotriomorphic forms. Veins of secondary quartz cross the section, replacing large crystals of feldspars in their paths across the section. Hematite occurs in irregular masses and in minute grains. It seems to have crystallized after the original rock had been altered by secondary forces. The needles of hematite surround and penetrate into the pseudomorphs. Large crystalline forms of pyrite are quite numerous, frequently completely blocking the wide veins of secondary quartz, showing them to be later than these veins. They are also fringed with hematite; one six-sided form appears included within a pseudomorph, but may be superimposed. Hematite frequently breaks across the pyrite and is, no doubt, the later mineral.

21. Iron ore in gneiss on Copper Zone.

Groundmass is a mosaic of secondary quartz and altered feldspar fragments. The few large feldspars that remain have been subjected to such pressure and distortion that they are hardly recognizable. They have wavy extinction and show always alteration and inclusions. Chlorite with dark brown interference colors, is frequent in large amounts throughout the rock. No epidote is present. Hematite occurs in large masses with a pronounced and highly developed radial structure. This radial structure proceeds from a center in the hematite and limited by radii from some other center. Needles also protrude into the groundmass, feldspars and chlorite. Cleavage planes are distinctly noticeable in certain portions of the hematite. It contains also inclusions of quarts chlorite and feldspars. Large masses of dark brown alteration products have hematite as a center. Chlorite fills veins across the section. Some calcite occurs in the groundmass.

Elevation of Planet Peak:

The elevation of Planet Peak, as recorded on the map, is the altitude determined by H. Bancroft, who states in his report that, "the elevation of some prominent peaks were determined by vertical angles."

The writer located roughly the position of the peak by triangulating in with the government monuments on Black and Monument Peaks. An average of aneroid readings and depression angles on the above peaks gave an altitude of 3107'. These two independent determinations would indicate the elevation assigned the peak is not far from its real elevation.

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